THE ENGINEER

A Seven-Day Journal

The Drainage of Firedamp from Mines

Two years ago a working party was constituted by the Ministry of Fuel and Power and the National Coal Board to prepare a report on the drainage of firedamp from mines. Its terms of reference included a study of the existing literature on the subject; a critical examination of the existing sites at collieries in this and other countries where methane drainage is being carried out or has been tried, with a view to determining the significant factors affecting each one; and reporting upon further desirable experimental work. The working party has now completed its report which has been submitted to the Chief Inspector of Mines and the National Coal Board's Director-General of Production. During its investigations, the party visited nine mines in the Rhur, the Saar and Belgium, where gas was being drained successfully. The report gives details of the geological and mining conditions and of the technique and safety precautions in the methane drainage systems seen in operation on the Continent. These, it is stated, have been considered in relation to British mining conditions. In some general conclusions, the report says that trials already being carried out by the National Coal Board have been designed broadly on lines recommended by the working party. So far, the results of the trials are encouraging and appear to indicate that gas can be drained by the cross-measure bore-hole method under a wide variety of conditions. The potential benefits to be derived from firedamp drainage are of such value that the working party thinks that the system should be developed vigorously in this country and should be applied, as soon as possible, wherever suitable conditions exist. It is therefore recommended that further trials should be started at a number of collieries, and should be designed to determine the amount and composition of the gas which can be drained at each pit, with a view to installing pipe ranges of suitable size for transporting gas to the surface and using it. The working party remarks that at the mines which it visited, where the methane was being utilised, the general experience was that the gas obtained was more than sufficient to pay for the installation, operation and maintenance of the drainage schemes.

The Diesel Engine Applied to Agriculture

In connection with the Smithfield Show and Agricultural Machinery Exhibition taking place at Earls Court, London, this week, the Institution of British Agricultural Engineers held an open meeting yesterday (Thursday) afternoon. A paper entitled "The Diesel Engine as Applied to Agriculture" was presented for discussion by Mr. C. W. Chapman, M.I.Mech.E. In the course of it, he emphasised that, on the modern farm, mechanisation was being applied to almost every task, calling for an increasing consumption of power. Sometimes, Mr. Chapman said, that could be obtained from electrical mains, but the bulk of that power had to be produced on the site of operations, calling for suitable prime movers ranging from around 1 h.p. for small pumps to upwards of 100 h.p. for large tractors. All such prime movers, Mr. Chapman pointed out, whether stationary or traction, must be reliable, economical and easy to maintain under the arduous conditions of the land. The paper went on to deal with diesel fuels and with the choice of engines for agricultural purposes, referring under the latter heading to engines for stationary and semi-portable duties and tractor engines. Summing up the matter, Mr. Chapman suggested that the diesel engine was becoming increasingly popular for agricultural use, partly on account of its economy, but largely on account of its reliability and freedom from electrical troubles. Most requirements, he said, were now catered for, although there were no suitable diesels in the 1 to 3 h.p. range. Another important point brought out in the paper was that simplicity should be the keynote of the design of an agricultural engine, Mr. Chapman considering that reliability, fuel economy and ease of maintenance should have precedence over absolute fuel economy. Tractor engines, he added, should be comparatively low in speed, and ought to be totally enclosed. In the latter respect, Mr. Chapman remarked, there was much to be desired.

Research in the Gas Industry

The seventeenth autumn research meeting of the Institution of Gas Engineers was held in London on Tuesday and Wednesday of last week. At the opening session a statement was presented by Colonel Harold C. Smith, deputy chairman of the Gas Council and chairman of the Gas Research Board, on the organisation for research in the industry. It was, in fact, a progress report on research arrangements specified by the Gas Act, 1948. Colonel Smith recalled in the statement that the Gas Council had appointed a research committee under the chairmanship of Sir Edgar Sylvester, and that on the committee's advice the Gas Council had established two research stations. The first was by agreement with the North Thames Gas Board, the Fulham laboratories of which had become the nucleus of a research station, under the direction of Dr. H. Hollings. More recently, a second station had been established in the West Midlands Gas Board area at Birmingham, and Dr. F. J. Dent had been appointed director of research. A third research station might be established at a later date. Colonel Smith said that, by agreement with the Gas Research Board, the work on complete gasification, which was being carried out at Poole, had been transferred to the Birmingham station, the research staff engaged on the work at Poole having accepted appointments at the new station. The Gas Council's intention was to accelerate the pace at which the work was proceeding. The Council's view was that valuable research work should proceed as quickly as possible and that the research workers who were engaged on it should not be discouraged by any change in the organisation for research. Furthermore, Colonel Smith stated, the Gas Council intended to collaborate in the most practical way with the member firms of the Society of British Gas Industries which were doing research of interest to the industry. It was also the Council's intention to disseminate the results of work carried out to those likely to be interested, and it was hoped that the platform of the Institution's autumn research meetings would be available for the discussion of those results.

Report on the Stobcross Railway Collision

This week there has been published the report of the Ministry of Transport's inspecting officer on the collision between two passenger trains which occurred on June 9th last at Stobcross, on the low-level line through Glasgow Central, in the Scottish Region of British Railways. An excursion train from Renfrew to Balloch was standing—with the brakes off—in the tunnel at the Stobcross home signal, when it was run into from the rear by a train from Glenboig to Maryhill, which was travelling at about 30 miles an hour under clear signal. The signalman at Stobcross did not lower the signals for the first train, which he had forgotten, but gave "train out of section" and accepted the second train. The report says that two independent failures in an electrical locking circuit enabled him to do that. Fortunately, there were no serious injuries to passengers or train crews. Colonel D. McMullen, the inspecting officer who conducted the inquiry into the causes of the collision, says in his report that the accident was remarkable as it resulted from three simultaneous failures—one of the human element and two of separate pieces of electrical equipment. The human failure was that of the signalman in the Stobcross box, who entirely forgot the excursion train, having made no entries for it in the train register. But, Colonel McMullen remarks, his state of health was such that he should not have been permitted to work in a signalbox. He was just over the retiring age and had not been medically examined as required before being re-employed. The two failures of electrical equipment, the inspecting officer states, are attributable to nothing but bad maintenance. After an accident at Glasgow Cross in 1949, special instructions were issued as to the maintenance of signalling and electrical equipment on the low-level lines. Those instructions, Colonel McMullen notes, have been repeated and amplified, a step which it is hoped will have the desired result.

A University of Technology

Lord Portal of Hungerford was the principal speaker at the 289th anniversary dinner of the Royal Society, which was held in London on Friday evening last. In proposing the toast of "The Royal Society of London" he said that, apart from rearmament, there was no project which ought to have priority over the foundation of a university of technology. Dealing with technological training, Lord Portal recalled the contribution made during the war by the application of science to the fighting services. But, he continued, from his own contacts and experiences he had gained the impression that this country's unsurpassed record in pure science had not always been matched in the past by what had been achieved in applying the knowledge gained. There was, Lord Portal suggested, a real and urgent need for this country to expand its capacity for training technologists, so that full use could be made of the human material of outstanding quality which Britain and the Commonwealth always had available. The denial to many good men of the class of training which their ability deserved—and the migration to the U.S.A. of many promising young men for technological training and subsequent employment were penalties for the inadequacy of training facilities here, and, Lord Portal added, were handicaps which this country could not afford to carry. Lord Portal went on to say that he thought the advice on this matter given by those to whom the late Government last consulted was a good deal too conservative. He did not suggest that the steps proposed for the better use of existing resources were valueless, for the expansion of university technology would be a very definite contribution. But, Lord Portal urged, nothing less would be adequate for the health of our industrial future than the foundation, as quickly as possible, of at least one technological university, with the greatest freedom to control its own affairs and with resources to enable it to attract the best class of teachers.

The End of an Era

BY EDWARD H. LIVESAY

No. IV—*(Continued from page 682, November 30th)*

CALGARY acts like a gateway in a barrier between two totally dissimilar worlds: to the west it opens into hundreds of miles of mountain and forest; to the east extends an even wider stretch of treeless prairie. It was the turn-around point of my journey from the coast, where I intended to rest a day or so before retracing my steps to Vancouver. In article No. II, Nov. 23rd, it was explained that a certain misunderstanding had arisen at Revelstoke, in the matter of No. 5935, (Fig. 21) the C.P.R. Company's last steam locomotive, upon which it had been promised I should travel to Calgary: the plan had miscarried, for when last seen, the engine was standing in the yard at the Selkirk Divisional Point and I had gone out on No. 5921. It was therefore essential, if this, one of the primary aims of the trip, were not to become the baseless fabric of a dream, that the return from Calgary should be made with No. 5935, so during the morning of the rest-day, a call was made at the station offices to find out whether anything had transpired in the night. Chance ordained that the truant and I arrived at the Depot simultaneously, the engine inbound from Revelstoke on "No. 2," which was running several hours late. This was calamitous: it meant that No. 5935 would probably be rostered to take "No. 1" back to the west at 11.15 p.m., another night trip, anathema to me as an observer, so to the Ogden shops I went, to ask that if possible this affliction might be averted, and so it was. "Sure! We have two other 5900s here—we'll put one of them on 'No. 1' and hold No. 5935 for the 'Dominion' tomorrow." Returning to the station with my mind at rest, I found my prompt action in emergency had forestalled the Assistant Superintendent, Mr. Lowthwaite, who also had been on the telephone to Ogden with the same end in view.

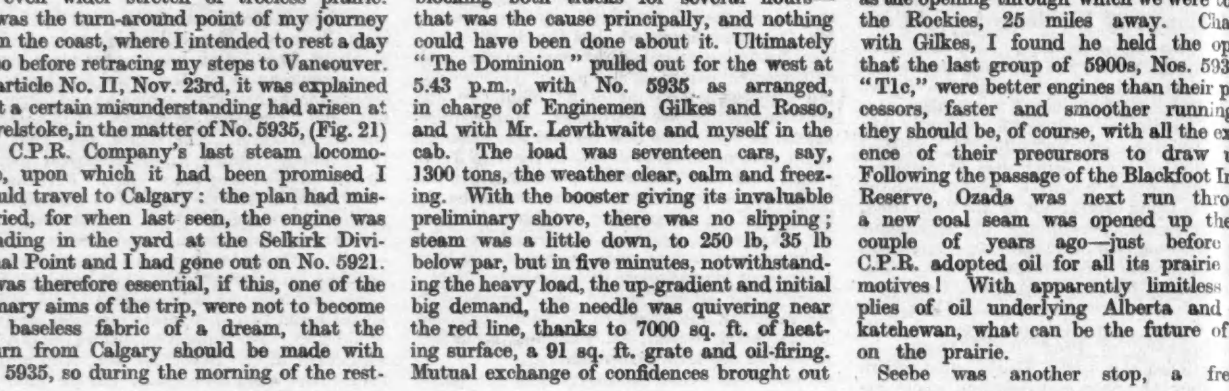


FIG. 21—ENGINE NO. 5935, "T1C" CLASS, C.P.R.

CALGARY TO REVELSTOKE

To the station next morning, through a nipping and an eager air—Calgary in mid-March, with 20 deg. of frost in the night, crisp snow and frozen puddles underfoot—to reassure myself at the Bulletin Board, only to find that once more we had all been too optimistic—"The Dominion" would arrive from the east after beating its way across 900 miles of blizzard-swept prairie at 5 p.m., eight hours late! The blizzard, however, was only partly responsible: a freight train travelling fast near Medicine Hat had piled itself up with a broken truck-frame, blocking both tracks for several hours—that was the cause principally, and nothing could have been done about it. Ultimately "The Dominion" pulled out for the west at 5.43 p.m., with No. 5935 as arranged, in charge of Enginemen Gilkes and Rosso, and with Mr. Lowthwaite and myself in the cab. The load was seventeen cars, say, 1300 tons, the weather clear, calm and freezing. With the booster giving its invaluable preliminary shove, there was no slipping; steam was a little down, to 250 lb, 35 lb below par, but in five minutes, notwithstanding the heavy load, the up-gradient and initial big demand, the needle was quivering near the red line, thanks to 7000 sq. ft. of heating surface, a 91 sq. ft. grate and oil-firing. Mutual exchange of confidences brought out that Gilkes was an ex-G.W.R. man, from Banbury; often on these runs I have come across British railwaymen at the throttle. At Brickburn, in the suburbs, the train went "into the hole" (*anglice* into a siding) to let an eastbound train pass; these have "priority," I believe, on single track.

Watching the driver's brake valve being worked, the fact emerged that No. 5935 was fitted with two compound Westinghouse pumps, resulting in a very quick build-up of pressure in the train-pipe of ultra-long trains, both passenger and freight. These "Selkirks" are dual-purpose engines and are allowed a maximum speed of 65 m.p.h.; I admit this seems to me too high as it must stress both engine and track. Away again into the foothills the speed rose to 50 m.p.h., at which 5935 was inclined to be a little rough, with a tendency to roll; the side rods were rather in evidence, too, though nothing was really objectionable. The "Pacific" No. 2390, a much smaller engine with proportionately lighter motion, had been far worse-riding, in comparision. I noticed the injector lever—under the driver's seat—being worked, which brought out the information that if this injector does not act promptly the feed-water pump comes into operation automatically.

The sun was sinking behind the jagged peaks ahead as a stop was made at Cochrane for water: afterwards, well on the up-grade, the speed remained at about 40 m.p.h., and the automatic permissive block colour-light signals began to stand out vividly green in the gathering dusk. Grey cloud-masses were hanging about the Rockies, forecasting a "Chinook" wind, warm and moisture laden, from the Pacific, as we neared "The Gap," visible against the skyline as the opening through which we were to pass the Rockies, 25 miles away. Chatting with Gilkes, I found he held the opinion that the last group of 5900s, Nos. 5930/35, "T1c," were better engines than their predecessors, faster and smoother running—as they should be, of course, with all the experience of their precursors to draw upon. Following the passage of the Blackfoot Indian Reserve, Ozada was next run through: a new coal seam was opened up there a couple of years ago—just before the C.P.R. adopted oil for all its prairie locomotives! With apparently limitless supplies of oil underlying Alberta and Saskatchewan, what can be the future of coal on the prairie.

Seebe was another stop, a freight-meet; the restart on an up-gradient emphasised the value of the booster in offsetting jerky getaways. Exshaw, the site of the Canada Cement Company's plant, shipping thirty cars a day; away again, a note was made of the quick and easy action of the air-powered reverse gear. Merely the release of a catch, the pressure of the hand on a trigger, the reverse-wheel spins with the whine of a power-drill—a click, and the gear is locked in position.

We were out of the rolling foothills now, and closing on the Bow River (Fig. 22) the gradient was easier, and the speed rose to 50 m.p.h. over the 110 lb gravel-ballasted track. Banff, and an eight-minute stop in the darkness, with only the outline of the great mountains showing faintly against a star-lit sky. Then Lake Louise, and a stop for water; the last 35 miles had been covered in 47 min (45 m.p.h.,) the fastest stretch since leaving Calgary, though we had climbed 516ft while doing it. From Louise to Stephen is 6 miles, over which 5935 really had to pull, lifting the train 280ft at 1·5/1·8 per cent to the Great Divide, where the mountain rivulet, carefully bisected, sends half its water into the Pacific via the Kicking Horse and Columbia and half to the Atlantic via the Bow, the Saskatchewan and Hudson Bay. A quaint conceit—we are on the watershed of the N. American Continent! At Stephen, 9.25,

the eastbound "Dominion" passed, running about six hours late; every schedule seemed to have been disrupted by something or other, with the weather directly or indirectly responsible for most of it. The upper spiral was entered at 9.54 and the lower spiral (Fig. 23) cleared at 10.5, "The Dominion" coming to a stand in Field at 10.15 p.m. The average speed over the 132 miles from Calgary had been 25·5, but this had involved a good deal, and it is much more impressive really than it sounds. One engine, No. 5935, had handled the 1300-ton load; there had been eight or nine stops, we had climbed 1899ft, and then gingerly descended the 14 miles from Stephen at 10 to 15 m.p.h. Personally, my respect for "The last of the Selkirks" was at a high level, and is here placed on record. At this point, Mr. Lewthwaite decided to "call it a night," and stopped off; I rather wished I could follow suit, but had it not in my heart to do so, though it was pitch dark and I could see nothing of importance either inside or outside the cab. So in company with Engineer Morris I carried on, out of Field, at 9.30 p.m. Pacific time, down the intricacies of the Kicking Horse to Golden, as my notes say: "Drifting—drifting—nothing much to note—speed very moderate round the curves of the K.H." The notebook goes on: "At Golden I retired to the train, having decided to return to Field with 5935 next day, so there was no object in carrying on in the cab any longer." Revelstoke, arrived 2.41 a.m., 8 h 21 min behind schedule. That, however, was in no way 5935's fault; both she and I had done our best, handicapped respectively by a late start and darkness.

Return to Calgary

Revelstoke, like Calgary, called for a prompt visit to the shops with a request that 5935 might do a quick turn-around and take the eastbound "Dominion" back over the mountains again for my benefit; as before, the favour was granted by Mr. Hartley, the superintendent, and the master mechanic. "The Dominion" left at 10.23 a.m., 88 min behind schedule, double-headed as usual, No. 5935 being the train engine and No. 5904 (Fig. 24) again pilot. The crew were Messrs. George and Young, and the load sixteen cars, say, 1225 tons. Though by all counts it was still winter, judging from the outlook—Revelstoke's streets were walled with 6ft snow-piles—the fireman's window, plus my half of it, were flung wide to the bracing mountain breezes, the first time I had enjoyed this freedom since leaving Vancouver. At Twin Butte—pronounced Bute for some quaint (American) reason—a stop was made at 11.05 to water No. 5904, which had come through from Taft. Two notes on my pad: "Seat (Sorbo rubber) extra comfortable—first day of spring." Following Albert Canyon are 3 miles of 2·2 per cent gradient, and the restart was a little troublesome, both engines cutting in their boosters and digging their toes in, but No. 5935 slipped more than once. The factor of adhesion of the "T1s" is 4·05, which is not over generous for a freight engine, practically what these machines are. The actual Canyon is a fearsome cleft in solid rock some 200ft deep; in the past a stop was always made to allow passengers to peer down into the depths, but now this privilege has been withdrawn. Shortly after, a couple of long snow-sheds are negotiated, with two tunnels forming part of the protection; infernally hot, these, (particularly when No. 5935 slipped *in medias res*, twice, and probably No. 5904 did, too), the choking sulphur fumes being worse than usual owing to my not having a cotton-waste filter ready. Another stop and restart on this 2·2 per cent gradient gave an entry "not 'difficult,' but both engines had little reserve of tractive power" on a slippery rail—the blue sky had disappeared behind a grey mantle and it was snowing quite heavily. One notices in the mountains that the track is very solid and well cared for, as, of course, it should be where conditions are potentially dangerous; the steel is 130 lb to the yard here. At one point Young drew my attention to a treeless gash down the flank of the mountains, with the Illecillewaet River at its foot, the scene some years ago of a "slide" which swept a snowplough into the torrent, killing most of the crew. The track was then brought over to the other side of the river. This affair had already been described to me by the engineer chiefly involved, Carmichael; if I remember rightly, he had gone back to the caboose for dinner, and the conductor was on the engine when the slide came down; he was killed, but Carmichael escaped. Some of the "scrap" can still be seen in the river.

Fig. 22—Alongside Bow River, Nearing Banff

Nearing Glacier, over 3000ft up, it was scarcely possible to see ahead through the whirling snow, but we emerged from the eastern end of the Connaught tunnel into sunshine. The tunnel is under Mount Macdonald (10,818ft); it was to avoid this mass that the line was taken through Rogers Pass, which meant a climb of 500ft and 4½ miles of snowsheds in 5 miles; some of them can still be seen clinging high up on the mountain side. The bore was completed in 1916; it cut the climb in half and shortened the distance by 4½ miles, curvature totalling 7 circles being done away with. The diesel-driven fans are at the west end, trains automatically switching to the left-hand metals; it is the longest double-track tunnel in N. America. A mile or so beyond the eastern portal the line crosses Stoney Creek bridge, one of the major engineering structures of the mountain section. The great depth of the gulch it spans, 270ft, called for a single-arch bridge 486ft long, the western end of it slightly curved. Surprise Creek is another stream crossed at a great height, 170ft, in this case by a truss; the torrent begins so high up the mountains it looks at first like a mere pencil-mark on the rock before widening and plunging under the bridge into the Beaver, where all these streams end up, the latter in turn losing its identity in the Columbia. The valley of the Beaver forms part of Rogers Pass, Beavermouth lying at the foot of it. Here No. 5904, the pusher, came off, and 5935 took water. There is a water gauge in the cab giving the level in feet, and an oil-fuel chart which reads: 1in=0·5 barrel, 12½in=5·8 barrels, 102·5in =124 barrels; 1 barrel=42 U.S. gallons.

The speed rose to 45–50 m.p.h. along the Columbia Valley, one of the few stretches in the mountains where such a rate is possible with safety. The river alongside was still mostly ice-bound, but the "break-up" was evidently not far off, patches of fast-flowing glassy-green water showing here and there. Here came a new experience; No. 5935, rounding a shoulder of rock, hit a snow-slide, not a very big one and fortunately snow only, but substantial enough to make her 330 tons shake and lurch and send a mass of snow shooting up her plough, her "winter garment," and right over the chimney, filling the cab with a fog of snow-dust. The slide had been on George's side, but there had been no time for him to take appropriate action—the engine was into and through it almost before he saw it. At the next stop, Golden, I got down to investigate, finding the front end a mass of packed snow covering every nook and corner, lodging even up by the diminutive stack—the smokebox is lagged—and along the running-board. Before the pusher could come on—for the Golden-Leanchoil climb—the coupler had to be chopped clear of snow, and several attempts were made before the jaws could engage, delaying departure until 2.21 p.m. A keen look-out for "slides," of snow or rock, is naturally a preoccupation at all times in the mountains, and the crews told me that this particular spring seemed to make it more than usually necessary.

The climb to Leanchoil, made with the help of a 2–10–0 pusher of older vintage, seemed to involve ultra-heavy work for both engines, the speed falling to 10 m.p.h., and No. 5935 losing her footing more than once. At Palliser I went forward to the veteran, riding to Leanchoil in her time-worn cab; it boasted the old type "pull-out" regulator, wheel-reverse and so on, and I have since wondered if perchance the engine was one

of the converted "Mallets," with both high and low-pressure cylinders between the two groups of wheels, which used to wheeze up the "Big Hill" in a cloud of steam from leaky flexible joints in the early 1900's; probably it was. They were 0–6+6–0, and were illustrated in "THE ENGINEER" of March 17, 1939. Though old and well stricken in years, the patriarch struggled manfully up the 2·2 per cent gradient, putting her best foot foremost, roaring harshly, trembling in every limb, earning my unstinted admiration, coupled with relief when I could go back to No. 5935's comfort and stability at

FIG. 23—ENTERING LOWER SPIRAL TUNNEL FROM FIELD

Leanchoil without offending either engine or crew; enough was as good as a feast on No. 5752 beside the waters of the Kicking Horse. It reversed on a "Y" and returned to Golden, where it would do the same thing before hooking on to the next eastbound train needing assistance: evidently tender-first running is not allowed over these winding, rock-bombarded miles. No. 5935 continued solo through Ottertail to Field and, the gradient being decidedly adverse, had all her work cut out, bringing the speed down to 15 m.p.h. However, there was no slipping nor stalling and "The Dominion" came to a stand in the Divisional town, smoky and drab, seemingly always to cower in the shadow of towering Mount Stephen, threatened by the overpowering might of other 10,000ft giants, at 4 p.m. Here I stopped off, reluctant to face again the sulphurous interiors of the Spirals after having gathered, as I judged, all the data on No. 5935 necessary. With two pushers ahead, No. 5935 pulled out for Stephen and Calgary, leaving me behind to fill in eleven hours before "No. 1," westbound, would give me a lift back to Revelstoke. The prospect was not too cheering, as there is nothing much to see at Field; sleep seemed the most attractive part of the programme and this I sought at the Y.M.C.A.—there is no regular hotel. But I had underestimated the possibilities of Field; a very likeable youngster, one of the shop staff, showed me all through the plant, roundhouse, &c., and, as a tit-bit, introduced me to the most complete electrically worked model railway lay-out I have ever seen, owned, built and managed by another railway man, whose chief joy it evidently was. Almost every imaginable detail of a railway was included in this beautiful miniature; the owner's pride in the fascinating replica was understandable, and I pictured what his reaction would be if he were moved somewhere else and had to dismantle the complicated paraphernalia or, worse still, leave it behind!

WESTBOUND TO REVELSTOKE

In the small hours of the following morning, "No. 1" westbound arrived, with No. 5919, one of the older "T1a" class," built in 1929, at the head, but I hardened my heart and went straight to a reclining chair in the train; there were still arrears of sleep to make up. Awaking several hours later, to find the sun rising and "No. 1" spinning along beside the Columbia, I got ready to take up my duties again at Beavermouth. The line follows the river through a broad and fertile valley across which many little streams find their way to the Columbia from the Van Horne and Dogtooth ranges. Just outside Golden is Edelweiss, a village of chalets, built for the Swiss guides employed by mountain climbers. Would that other B.C. villages gave as much attention to æsthetics, but they don't; there are not half-a-dozen villages in the Province fit to look at; most are nothing but collections of sheds, shacks and shanties, all the worse by contrast with Nature's glories all around. The heavy growth carpeting the Beaver and Columbia valleys gives protection to many deer, moose and elk; at one point on the eastbound trip along here we came upon a huge moose standing on the embankment with his forefeet almost on the metals, and not until the engine was half-a-dozen yards from him did his courage fail and he reluctantly, unhurriedly, withdraw into the deep snow alongside. Bears are common, too, though, of course, not in the winter. The line enters a great canyon at Donald, remaining in it to Beavermouth, where the Beaver and Columbia join, and here, to my surprise, no stop to pick up a pusher was made, No. 5919 continuing up the aclivity and on through the Connaught tunnel solo, non-stop to Glacier, where I joined her for the descent to Revelstoke. It was snowing on this side of the Selkirks and continued to do so at intervals on the way down. The fireman was not too complimentary to No. 5919: "She's one of the old class, only a freight engine really." "So they all are," I nearly ventured, but forbore—he added it was difficult to keep time with them, I wondered why; the power and chief dimensions of all the three classes are much the same, and I have never heard anyone else say this. Diplomatically I kept quiet—never argue in a cab! The weather, too, came in for acid criticism from everyone: the whole winter seemed to have been unusually troublesome, what with heavy snow, sudden thaws and "slides" of both snow and rock.

Albert Canyon and a stop for orders; I jotted down "ceased snowing and patches of blue sky appeared—the veteran's riding good, explanation being she had only come out of the shops a month before." The exhaust steam and steam-chest gauge had been removed from this engine, and I was told, not for the first time, that its room was preferred to its company. The concensus of opinion among enginemen has certainly been that it is more bother than it is worth, not one engineer in ten paying any attention to it. "No. 1" came to a stand in Revelstoke at 8.35 a.m.; and now I find noted "Pleasant trip—good riding engine—weather rainy." The four days with the "Selkirks" were over and it is with regret I have to recognise the fact that I may never ride with them again in the mountains. Their day and mine—in that locality—are over.

I had intended to watch them at work in heavy freight service, but my excursion had already extended to a greater length than planned and I contented myself with second-hand information. Sometimes three engines are employed on one train in the mountains—even four, I believe—in which case one is put at each end and one in the middle. Under these conditions the atmosphere in the Spiral tunnels becomes very sultry; enginemen have been known to collapse. The two tunnels are 3255ft and 2922ft long respectively, the 2·2 per cent gradient being compensated to 1·6 per cent inside them, and a ninety-odd car freight train with three or four engines can result in the two at the head emerging directly above the "pusher" going in. In preparation for the near future

FIG. 24—SNOWPLOUGH AT FRONT OF ENGINE NO. 5904

of the "T1abc" engines, on freight work east of Calgary, experiments have already been made there and one "T1c" has handled 4000 tons without any difficulty on the generally rising westward gradient. It sounds impressive; when I feel I *must* see a "Selkirk" in action again, it might even induce me to go to the prairie on purpose.

(To be continued)

Hydro-Electric Power in the Isere Catchment of the French Alps

No. III—THE ROMANCHE AND ARC

(Continued from page 684, November 30th)

THE River Romanche is one of the principal Alpine rivers and, with its tributaries—Le Vénéon and L'Eau d'Olle, it drains the massif of Oisans, of which the highest peaks are La Meije (3983m) and La Barre des Ecrins (4102m). In contrast to the comparatively recent development of the Drac, which was described in Part II of this article, last week, the Romanche has numerous power stations along its course, some of them many years old. At an early stage in the history of hydro-electric power development, power stations were built along the Romanche valley, together with a substantial metallurgical and electro-chemical industry, which took advantage of the power so readily available. Before the nationalisation of electricity in France, the cost of power in Grenoble was less than anywhere else in the country, owing to the extent of the neighbouring hydro-electric developments. Since power from the river was so convenient to harness, however, the early power stations are not of great technical interest at the present time and it is to recent works that we must look for the more interesting projects.

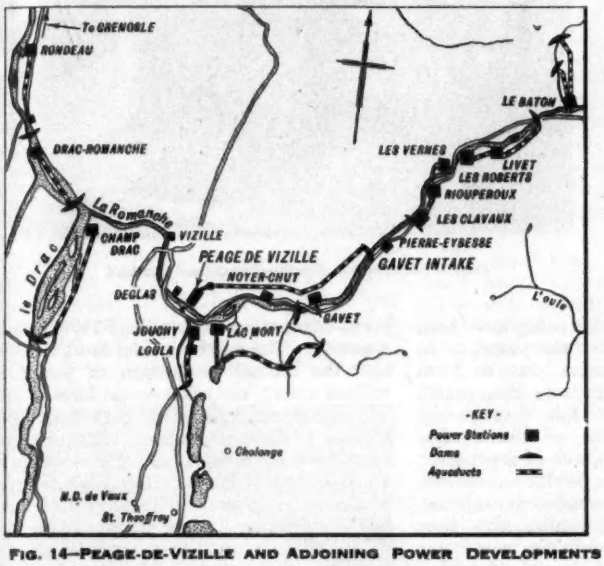


FIG. 14—PEAGE-DE-VIZILLE AND ADJOINING POWER DEVELOPMENTS

The first large storage dam to be built in France, the Chambon dam, was constructed in the early nineteen-thirties on the upper Romanche, and it now serves to provide seasonal storage and regulate the river flow through the extensive series of power stations below it down to the confluence with the Drac and to Grenoble.* The dam is a gravity structure about 90m high above river-bed level, the length of the roadway along the crest being about 1000m. The storage capacity of the reservoir is 54 million cubic metres.

At present the Chambon dam is the highest development on the Romanche but it may be recalled that, in Fig. 1, a project in the design stage was shown marked "Romanche Superieure." This project is an example (there is a second one above the dam of La Girotte) of a development taken right up the mountainside to the glacier from which the headwaters of the stream are derived. In this case it is planned to build a dam on the slopes of La Meije, at the highest available point below a glacier forming a left bank tributary of the Romanche. A second dam will be built on the other side of the valley, both of the reservoirs so formed supplying a power station at the level of the main stream at Villar d'Arene.

PEAGE-DE-VIZILLE

A recent development much further down the Romanche is that of the power station of Peage-de-Vizille, which was the first power station to be designed and built by the nationalised Electricité de France. It has an installed capacity of 58MVA and an annual production of about 280 million kWh and replaces the two old power stations of Gavet and Noyer Chut, which did not completely utilise the resources of the river over this particular length and were both in need of replacement. The lay-out of the scheme and of the two power stations which have been replaced may be observed in the accompanying diagram (Fig. 14), which also gives an idea of the various power stations nearby.

The intake works of the Gavet power station were reconstructed to take the increased flow required for the new power station and the reconstructed works are shown in the illustration, Fig. 15. For a considerable length the old tunnel was enlarged to give an unlined tunnel of approximately rectangular cross-section but further downstream a new unlined tunnel of horse-shoe cross-section was built.

There is a surge chamber at the downstream end of the tunnel, followed by a pressure pipe-line built in tunnel down the hillside (for amenity), with a bifurcation at the level of the power station, one pipe leading to each machine. The chamber limits the pressure surges by overflowing, a discharge canal with a capacity of 45 cubic metres per second being provided. This canal joins the long tail-race—a concrete-lined open channel—which leads back into the Romanche.

There are two horizontal Francis turbine sets, each of 29MW, in the power station. As was mentioned earlier, the Francis turbines each have a double runner. These machines have been built by the consortium Neyrpic-Alsthom-Charmilles, with the object of giving a more compact lay-out than that of a single alternator driven by a turbine on each side of it. Some "teething troubles" were experienced with these machines, particularly from cavitation, but they have now been operating satisfactorily since the beginning of 1950. The erection of one of them is shown in the illustrations, Figs. 16 and 18, from which the configuration of the double runner and one of the two draught tubes may be clearly seen. The machine speed is 500 r.p.m., and each one is connected to an alternator, which generates at 10kV. There are two three-phase transformers, 10/60kV, each of 30MVA capacity, feeding a high-tension grid.

The turbo-alternators operate under a net head of 132m to 141m, each one absorbing a flow of 22·5 cubic metres per second at normal power. The runaway speed of the turbines is 950 r.p.m. Each turbine is directly coupled to the alternator and consists of a scroll casing of cast steel, distributor and guide vanes of cast steel, each with its own bearings, a stainless steel double wheel, as shown in the illustration, and a

* The Chambon dam was described in some detail in our issues of April 24 and May 1, 1936, pages 444 and 454.

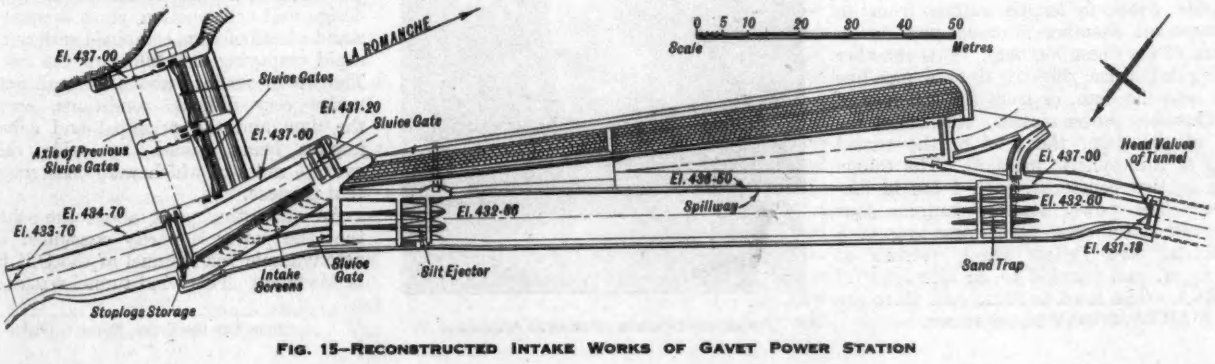


FIG. 15—RECONSTRUCTED INTAKE WORKS OF GAVET POWER STATION

thrust collar to take residual thrust in either direction. Lubrication is by a pump driven from the main shaft of the turbine, with an electric standby pump controlled by a d.c. motor, which is automatically brought into use if the main pump breaks down. The auxiliaries include a butterfly valve at the intake controlled by hydraulic servo-motor units, and a governor controlled by pressure oil.

The turbines at Pont-en-Royans power station, which were mentioned in Part II, are generally similar in construction to the ones described above, being of 15,500 h.p. to 16,250 h.p. and working under a head of 102·7m to 107·6m. Their normal speed is 500 r.p.m. and the runaway speed 900 r.p.m., the normal flow through each machine being 12·72 cubic metres per second. The guaranteed efficiencies of these machines at different loads are shown in the accompanying table.

Load	Efficiency, per cent
10/10	89
9/10	90
8/10	89·5
7/10	87·5
6/10	85
5/10	83·5

As was to be expected, considerable care was given to the appearance of this power station, as it was Électricité de France's first design, and is situated in pleasant surroundings. It is shown in Figs. 17 and 19. The spacious interior, with the control room overlooking the machines, may be observed; the exterior is typical of several power stations constructed in this region, the height of the machine room being expressed by the tall windows, and a pitched roof being provided to cope with the winter snow. As a contrast, Fig. 20 shows the power station of St. Guillerme, which was completed in 1929.

St. Guillerme power station is supplied by a tunnel 5½km in length leading from an underground chamber situated just down stream of the Chambon dam. This chamber is supplied either directly from a pipe-line built into the dam, or from the tail race of the Chambon power station, which is at the foot of the dam, the flow in the tunnel being at atmospheric pressure. The tunnel leads to two penstocks, each 1·5m in diameter. The power station contains four turbo-alternator sets, each consisting of a horizontal axis Pelton wheel, turning at 500 r.p.m. and coupled to an alternator of 6·5MVA. The head is 232m and there are four 6·5MVA, 6/60kV transformers.

FIG. 16—TURBINE RUNNER—PEAGE-DE-VIZILLE

THE ARC

The route from Grenoble to Briançon (R.N.91) follows the Romanche valley up past the site of the Romanche Superieure development, almost to the source of the river. It is possible to travel by way of the R.N.202, over the Col du Lautaret and the Col du Galibier, reaching an altitude of some 2650m and then descending into the valley of the Arc at St. Michel de Maurienne. The water power resources of this valley have been extensively developed over the years, as in the case of the Romanche, due to local industry and the main railway line, which passes up the valley to Italy through the Mont Cenis tunnel. One of the typical sights of the valley is the arch of a penstock forming a self-supporting bridge across the river. The Pelton wheel is much in evidence, as there are tributaries which give sites for storage at a high level in the mountains on each side of the valley, combined with a pipe-line down to a power station beside the Arc. The highest head of any of the French Alpine power developments, 1145m, is at Bissorte, which is a little upstream of St. Michel and utilises a left-bank tributary (the highest head in France is that of Portillon power station in the Pyrénées, where the gross head is 1414m—4639ft). There is a gravity dam and a penstock leading down to a power station containing Pelton wheel turbo-alternator sets totalling 87MW installed capacity. The maximum net head is 1079m, and the annual production of power 175 million units; the scheme was built in 1932.

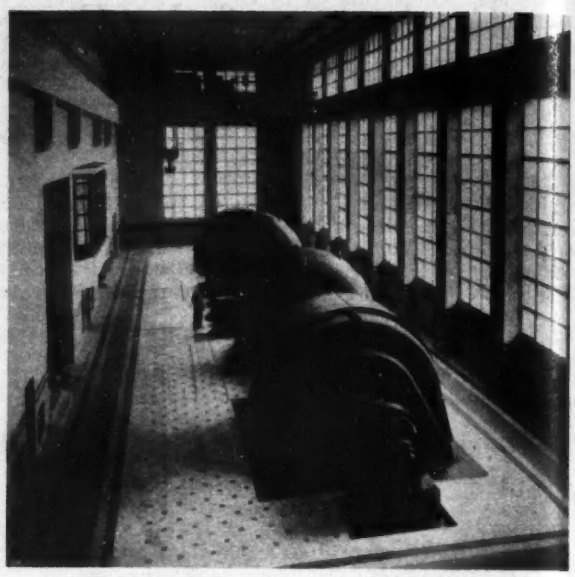


FIG. 17—MACHINE ROOM—PEAGE-DE-VIZILLE

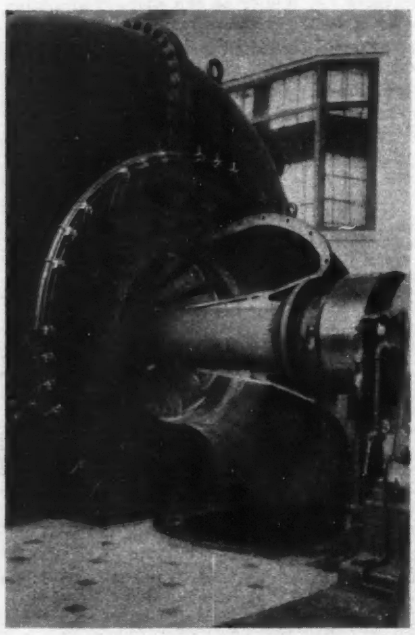


FIG. 18—DOUBLE FRANCIS TURBINE

Another example of a high head power station is that of Aussois, which has only recently been completed. The scheme has a gross head of 860m; it consists of intake works on the Doron de Termignon, followed by a collecting tunnel about 16km long at an altitude of 2000m, with seven intermediate intakes along its length. This tunnel supplies a reservoir on the Avrieux, a mountain torrent with a catchment area of 9 square miles. The reservoir has a capacity of 3250 acre-feet, and is formed by a dam about 30m in height, which has been built in two parts, on each side of a central "island" of rock, where a substantial abutment has been built. The left bank opening is closed by an arched dam with a length of 103m along the crest, and the right bank opening by a gravity dam with a crest length of 202m, which is parabolic in plan, following the line of a rocky ridge upon which it is founded. The dam is faced with stone blocks to give protection from frost and ice.

A tunnel about 2km in length leads from the reservoir to a surge shaft, and from thence a single auto-fretted pipe-line leads to the power station. The tunnel required careful design and construction, since it must withstand a head of 70m, combined with relatively rapid emptying and filling of the reservoir. The works outlined above were all executed under very difficult conditions, access to the dam and the principal and subsidiary intakes being gained by cable railways over 15 miles of which were constructed for that purpose.

An interesting point about the scheme is that the power is partly consumed by the aerodynamic wind tunnel of the O.N.E.R.A. at Modane.† This wind tunnel was acquired

† See THE ENGINEER, March 2, 1951.

from Austria after the war, by way of reparations for the French installations, which had been destroyed. It was driven directly by water turbines, and it was therefore necessary to find in France a scheme having the same hydraulic characteristics, and the one at Aussois was selected. Since the wind tunnel functions irregularly and for short periods only, it was decided to build a power station beside it, to utilise the power when the wind tunnel was idle. This arrangement necessitated a redesign of the Aussois scheme (work upon which was started in 1939 and abandoned in 1940), to meet the special requirements of its dual capacity. The annual production of the scheme is about 325 million units, of which some 60 million are consumed by the wind tunnel.

The power station has three Pelton wheel turbines, which are horizontal-axis machines of 41,000 h.p., turning at 600 r.p.m., with two jets. The two turbines of the wind tunnel are also Pelton wheels and each one of them drives one of the wind tunnel fans directly. They are each of 52,500 h.p., under a head of 787m, and have a variable speed with a maximum of 250 r.p.m. On account of these characteristics, the diameter of the wheel is large (5m), as may be observed from Fig. 21; there are twenty-six buckets and the wheel itself weighs 32 tonnes. The speed regulation of these turbines can be varied over very wide limits and presented a new problem in turbine regulation, which was solved by the use of an electronic governor. The single penstock of the scheme is used to supply the power station and wind tunnel alternately or together at part loads, as required. The wind tunnel load can reach the total capacity of the penstock, but for a very short time only. It will be seen that the placing in parallel of two such dissimilar hydraulic installations gave rise to a unique design problem.

FIG. 19—PEAGE-DE-VIZILLE POWER STATION

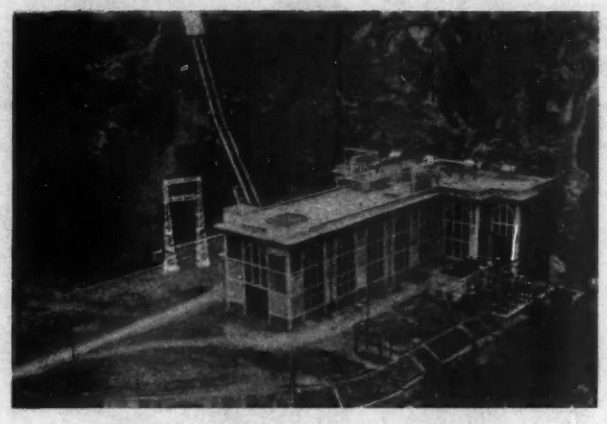


FIG. 20—ST. GUILLERME POWER STATION

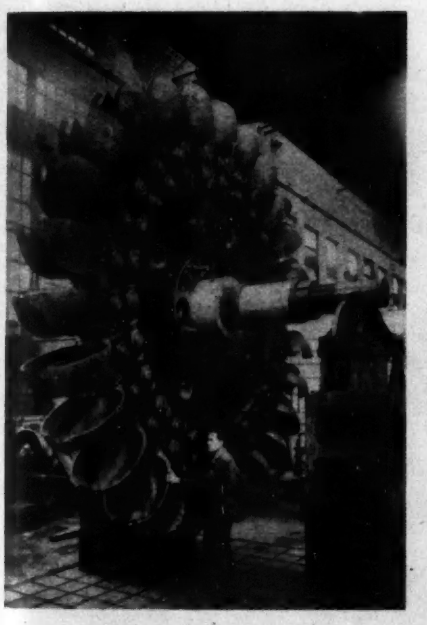


FIG. 21—TURBINE RUNNER—MODANE WIND TUNNEL

The project at Arvans (see Fig. 1) was built under difficult conditions similar to those encountered at Aussois. This scheme was finished early in 1950 and consists of intake works on four streams at levels of about 1225m and tunnels leading to a surge chamber and penstock, followed by the power station with a tail-race level of 640m. There are two 13·5MVA horizontal Pelton wheel turbo-alternator sets in the power station.

A project which recently aroused considerable interest amongst French and Italian engineers was the development proposed at Mont Cenis. A large output—about 1000 million units a year for an installed capacity of 400MW—was envisaged and it was proposed to utilise Lac du Mont Cenis as an important seasonal storage reservoir and to construct a dam at its outlet. Before the war the Lac du Mont Cenis was in Italian territory and as a result of the peace settlement a certain area of land up the lake was ceded to France, to provide pasturage for the cattle of certain local communes. The prospect of an extensive hydro-electric development, the catchment stretching across both sides of the frontier, led to some discussion as to the positioning of the power station and the necessary diversion of the head streams. The Arc was to be diverted at a high level into the storage lake; the power station was first to be in the Arc valley in French territory, with a diversion tunnel passing under the reservoir, but it was later suggested that it should be situated in the valley of the Cenischia, which is the natural outflow of the Lac du Mont Cenis, in Italian territory. At the present time it is understood that investigations are not still continuing because the geological survey of the reservoir site indicated that the bedrock was too faulted and porous for development as originally contemplated. It was therefore decided that the headwaters of the Arc should be diverted northward to augment the catchment supplying the large reservoir at Tignes, which is described later in this article in connection with the development of the upper Isere and its tributaries. Construction of the Mont Cenis project therefore seems unlikely; however, should the scheme be considered again it will probably be on a smaller scale, the reservoir being supplied by Italian and French torrents nearby, but not by the Arc. For geological reasons a reservoir sufficiently large to require the headwaters of the Arc to supply it cannot be built.

THE BREDA

Reference to Fig. 1 will indicate that the length of the Isere from the point where it is joined by its principal tributary, the Arc, down to Grenoble, is not favourable for power production, the slope being about 1 in 1000. As may be seen, however, the small tributary of La Bréda has several power stations along its length. The most recent of these is at Pontcharra. This scheme has an annual power production of about 40 million kWh, with two Francis turbo-alternator sets, each of 6·6MVA, working under a gross head of 170m.

(To be continued)

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

IDENTIFICATION SCHEME FOR AIRCRAFT PIPE-LINES

No. M23 : 1951. This standard has been prepared at the request of the Air Registration Board and approved by the Aircraft Industry Standards Committee for the purpose of providing a scheme to indicate, on an international basis, the function of a pipe system in aircraft. Identification is provided by the combination of a written description of the main function of a line with one of a series of geometric symbols suitable for international use. It is independent of the use of colour in order to avoid confusion with existing codes. Part I provides a system of schematic indentification of pipelines for basic services in aircraft. Part II relates to the identification of subdivisions of those services. Price 2s., post free.

PORTABLE FIRE EXTINGUISHERS OF THE CARBON TETRACHLORIDE TYPE

No. 1721 : 1951. This is a further document in the series of standards covering portable fire extinguishers. It is an entire revision of that part of B.S. 740 which covered carbon tetrachloride fire extinguishers. All types of carbon tetrachloride fire extinguishers are now provided for, and the standard defines what is meant by the various types as follows:—Hand pump type, gas container type, constant-pressure type, and air pump type. In addition, the standard formulates details of the materials to be used, the type and dimensions of the various parts, as well as details of construction. The standard furthermore gives methods of testing the fire extinguishers at various stages of manufacture and provides details of marking. Appendices give comprehensive details of fusion and resistance welding. Price 4s., post free.

HOT STRIP MILL AT ABBEY WORKS, STEEL COMPANY OF WALES

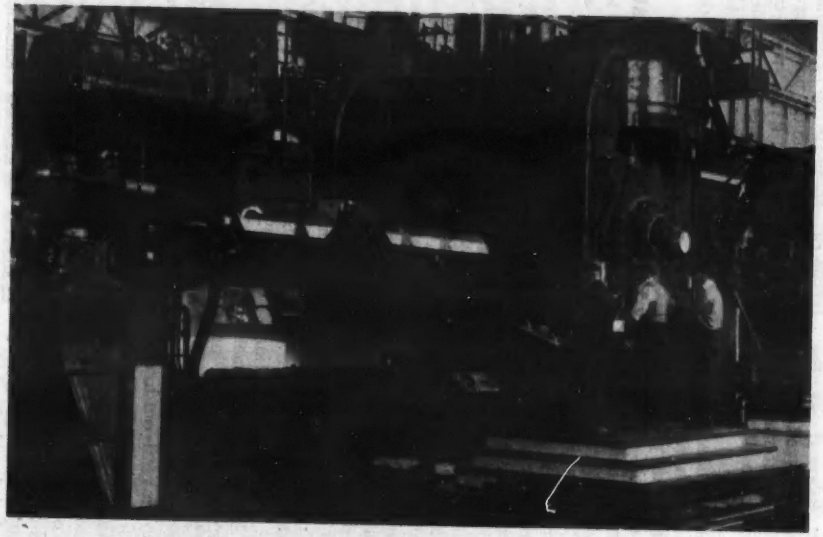


FIG. 27—BROADSIDE MILL

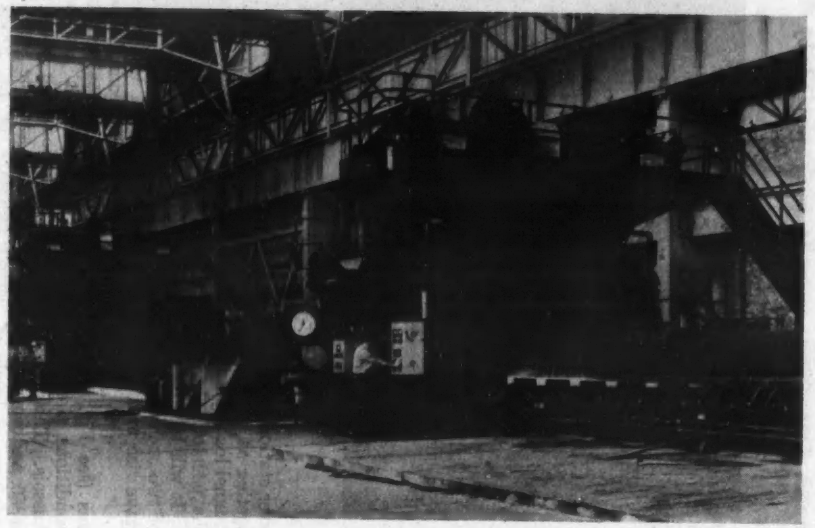


FIG. 28—ROUGHING MILL

FIG. 29—FINISHING MILL

FIG. 30—FINISHING STANDS AND RUNOUT TABLES

The Works of the Steel Company of Wales

No. VI—(*Continued from page 691, November 30th*)

No. 1 Roughing Mill (Broadside Mill)

FROM the scale breaker the slabs pass along to a four-high broadside mill with 42in diameter work rolls, 54in diameter back-up rolls and 130in long barrels, the back-up and work rolls being carried on "Morgoil" and Timken roller bearings respectively. It has slab turntables in front and behind which are used to turn half-length slabs (maximum 8ft 6in long) 90 deg. and back to proceed through the mills. As can be seen from the photograph reproduced in Fig. 27, a slab pusher is situated at the entry side of this mill, and it is followed by a squeezer, which aligns the slab before it enters the three-stand roughing train. This horizontal slab squeezer has a hydraulically operated hold-down and the platen is fixed during the squeezing operation. Its operating head is adjustable and has a working stroke of 7in, sufficient to give a good clearance between the heads for slabs to enter freely.

The broadside mill is driven by a 3500 h.p. three-phase, 50c/s, 11kV slip-ring induction motor. Its synchronous speed is 500 r.p.m. and, like the scale breaker motor, it is arranged for 20 per cent speed drop at 100 per cent overload, the flywheel in this instance having a stored energy of 70,000 h.p.-second. Since the broadside mill motor runs at a sufficiently high speed there is no external fan required for the closed air circuit system; consequently the thermostat in the vent core ducts is not required. Otherwise the two motors are similar. The rotor control gear is generally similar to that described for the scale breaker, but, being larger, it differs in detail construction. Variation of the point at which the torque motor comes into action can be carried out by the three methods mentioned for the scale breaker, but the most convenient one is the first. The balance weights have slightly different arrangements in the case of this controller, since the pilot motor operates one set and the torque motor the other, and the operating point of the torque motor can be varied by transferring the weights. At starting, the pilot motor weights rest on the torque motor weights and the two sets together cause the dippers to rise to the resistance "all-in" position. When the main switch is closed an auxiliary switch causes the pilot motor to raise its weights, but the torque motor weights, being insufficient to balance the dipper weights, allow the dippers to fall until checked by the torque motor. Automatic regulation then takes place as described for the scale breaker. When the main switch is opened another auxiliary switch causes the pilot motor to lower its weights on to the torque motor weights and thus raise the dippers to the "all-in" position, ready for the next start.

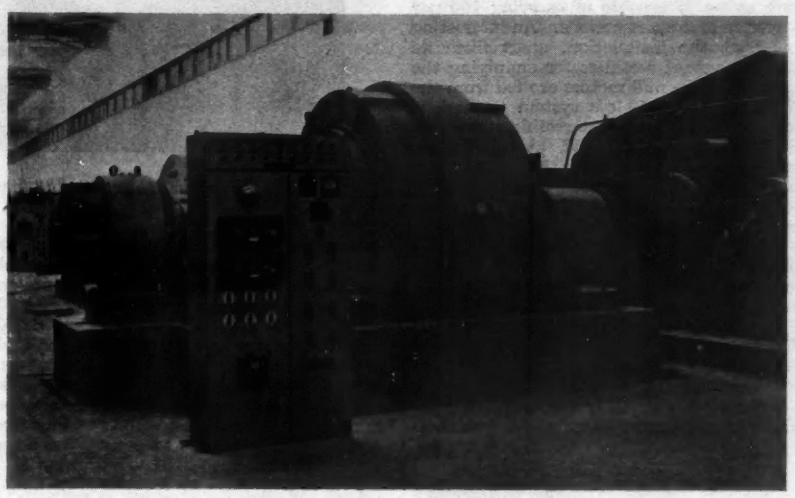


Fig. 32—4500 H.P. Roughing Mill Motor

Nos. 2, 3 and 4 Roughing Mills

Stands No. 2 and 3 are four-high mills having 36in diameter work rolls with 54in diameter back-up rolls, and No. 4 mill has 27in diameter work rolls with 54in diameter back-up rolls; all the rolls have 80in long barrels. A vertical edging attachment is fitted to each of the mills. Each mill is driven by a 4500 h.p. motor (Figs. 31 and 32), and the edgers have 200 h.p. motors. The 4500 h.p. mill motors are three-phase, 50 c/s, 11kV, 500 r.p.m. salient-pole synchronous machines, each having a cast steel rotor and solid poles with bolted-on shoes retaining the field coils. The rotor body is solid except for a hole bored through the rotor for inspection purposes, and the shafts are stubs bolted to the ends of the cast steel body, making a robust unit suitable for mill service. Since the poles are solid no damper windings are required in the pole faces, and the machines can be started and synchronised by the eddy currents induced in the poles when a reduced voltage is applied on the stator. The pull-out torque of the motors is three and a half times full load.

Excitation current for the field windings comes from a direct-coupled exciter which is arranged with the usual shunt winding, and another field winding to increase the excitation with the loading on the main motor. This increase is accomplished by connecting a series transformer in the stator circuit of the synchronous motor. The current from the secondary of the series transformer is led to a rectifier, whence the rectified current passes through the exciter auxiliary field winding. This scheme enables a given machine to deal effectively with the high peak loads encountered in such drives. It also enables the machine to maintain a good power factor on high loads.

The motors are also capable of inching duty; for this service the starting chokes have an extension to the ordinary winding. This extra winding is switched on for inching by opening a circuit breaker across it, and increasing the impedance to such a value that inching of the motor can be conveniently carried out by operating a push button. For normal starting the inching winding is short circuited.

In other respects the equipment of the synchronous motors is similar to that for the scale breaker motor, including closed air circuit ventilation and the special device for preventing unwanted reversals when the quick stepping arrangement is used. The motors, described above, for driving the scale breaker, the broadside mill and the three roughing stands at the roughing end of the 80in continuous hot strip mill were supplied by the Metropolitan-Vickers Electrical Company, Ltd.

Between the last roughing mill (Fig. 28) and the first stand of the finishing mill (Fig. 29) is a 150ft length of roller table (upon which a plate can be held, if necessary, to obtain the correct finishing temperature), a cropping shear and a pinch roller scale breaker. The rotary shear crops off the front and back ends of the strip, after which the pinch roll scale breaker cracks any scale formed during rolling.

Six-Stand Tandem Finishing Mills

Each of the four-high six finishing mills (Fig. 30) have 80in long work rolls, 27in diameter with 54in diameter back-up rolls. As in the case of the other rolling mills, "Morgoil" bearings are fitted on the back-up rolls and Timken roller bearings on the work rolls. Between each finishing stand, and ahead of

Fig. 31—Continuous Mill Motor Room

the first one, are sets of chutes and guides and situated between each stand is a looper roll.

Each stand of the mill is driven by a d.c. motor. The first two stands (F.5 and F.6) are driven through gear units, and the remaining four stands (F.7, F.8, F.9 and F.10) are direct from the motors (Fig. 34).

The ratings of the mill motors are shown in the following table :—

Hot Finishing Mill Motors

Stand No.	Motor h.p.	Motor speed (r.p.m.)
F.5	4500	125–282
F.6	4500	125–282
F.7	5000	78–156
F.8	5000	105–210
F.9	5000	125–250
F.10	4000	132–296

Each motor is capable of carrying 100 per cent overload for short periods. An interesting point about the installation, apart from its size, is the use of rectifiers for supplying the mill motors. The mill motors are fed from the 11kV, three-phase, 50 c/s system through a bank of B.T.H. mercury-arc rectifiers having a total capacity of 21,000kW at 800V. The diagram (Fig. 33) shows the elementary connections. It will be seen that the power to the rectifier is fed through five separate main oil circuit breakers and then through reactors and phase-shifting auto-transformers to the rectifier transformers.

There are a total of thirty rectifier tanks, permanently sealed, pumpless, steel tank units, the capacity of each tank being 700kW at 800V. (It should be noted that in Fig. 33 each diagrammatic rectifier represents a group of three tanks.) Each rectifier tank has six anodes and is provided with control grids. The main rectifier transformers have their primaries alternately star and delta, so that each group of six rectifier tanks forms a twelve-phase rectifier, and the phase-shifting auto-transformers are arranged to give the groups phase displacement respectively of minus 12 deg., minus 6 deg., zero, plus 6 deg. and plus 12 deg., the result being to produce at the busbars the equivalent of sixty-phase rectification. This has the effect of suppressing all harmonics below the fifty-ninth, reducing telephone interference to a very small value. The purpose of the reactors is to limit the fault current in the five main circuits.

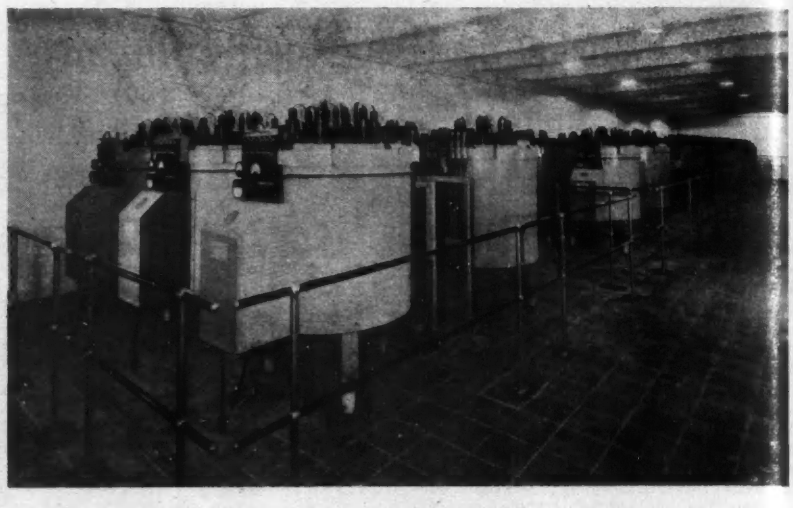
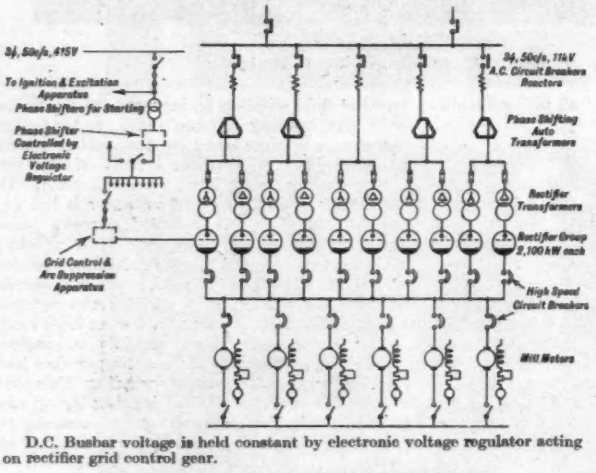


FIG. 35—RECTIFIERS FOR HOT FINISHING MILL MOTORS


3ϕ, 50c/s, 415V
To Ignition & Excitation Apparatus
Phase Shifters for Starting
Phase Shifter Controlled by Electronic Voltage Regulator
Grid Control & Arc Suppression Apparatus
3ϕ, 50c/s, 11kV A.C. Circuit Breakers Reactors
Phase Shifting Auto Transformers
Rectifier Transformers
Rectifier Group 2,100 kW each
High Speed Circuit Breakers
Mill Motors

D.C. Busbar voltage is held constant by electronic voltage regulator acting on rectifier grid control gear.

FIG. 33—SIXTY PHASE RECTIFIER DIAGRAM

Each of the ten rectifier groups feeds the d.c. busbars through a high-speed circuit breaker, also each of the motors is fed from the busbars through a high-speed circuit breaker. In addition to the protection afforded by these and the main a.c. circuit breaker, arc suppression is provided on the rectifiers by suitable control of their grid circuits.

Each mill motor has associated with it an individual exciter set. The mill motors are started up under light- load conditions only, starting being done by raising the voltage of the rectifiers from zero to 800V by operation of their grid circuits. When full voltage is obtained, it is maintained constant by an electronic voltage regulator, which also operates on the grid circuits. A further electronic voltage regulator maintains constant voltage on a service exciter which supplies the excitation for the mill motor exciters and control equipment. For stopping the motors quickly they are loaded on to dynamic braking resistances by means of contactors.

All the electrical equipment is controlled from two control desks. One of these is the mill operator's desk mounted in the control pulpit, from which the operators can control starting and stopping and synchronise the speed of the six mill motors. The second desk is located in the motor room and is under the control of the motor room attendant. This desk controls the oil circuit breakers, exciter sets, ventilation motors, and gives full indication of all circuits.

Ventilation of the mill motors and rectifiers is on the closed circuit recirculation system. By means of fans the air is recirculated through the machines or rectifiers and air coolers, and the inevitable losses are made up from an air supply through "Precipitron" filters. In the case of the mill motors separate fans extract the commutator cooling air with its brush dust to prevent it being carried round the main circuit.

The a.c. cables are paper or cambric insulated, and the d.c. busbars and connections to mill motors are of copper strip mounted on insulators. The positive and negative busbars are spaced as far as possible apart, one on each side of the basement.

The electrical drives for the hot finishing mill, as described above, were supplied by the British Thomson-Houston Company, Ltd.

Strip passes out of the last mill stand on to the 310ft long run-out table provided with water cooling, illustrated in Fig. 30, and travels through a rotary flying shear built to cut 72in wide, ¼in thick material into 15ft to 40ft lengths. Strip for coiling passes along the hot run-out table at speeds of up to 200ft per minute to two collapsing mandrel down-coilers. As the coils are stripped from the mandrels on those machines, they are tipped over to rest end-on on a conveyor which carries them up an inclined ramp, through a weight-recording station and out to a storage area. Sheets cut in the flying shear pass straight across the roller tables at the coiling machines to a piler.

Controls for each section of the mill train are grouped at stations from which the operator has a clear view of the material being rolled. All of these control points are linked together by a loudspeaker and microphone system, through which the operators can freely communicate with one another.

FIG. 34—FINISHING MILL END OF MOTOR ROOM

(To be continued)

Some Fuel and Power Projects*

By H. ROXBEE COX, Ph.D., B.Sc. (Eng.), M.I.Mech.E.†

No. III—(*Continued from page 686, November 30th*)

RETURNING to the immediate target just mentioned,‡ a "firedamp" gas turbine has been ordered by the Ministry from the English Electric Company, Ltd. Basically, the engine is the same as the coal-burning engine which this company is making, and perhaps in consequence the most practical engine using firedamp and auxiliary coal may be the descendant of these forebears. The first engine will, however, employ as the auxiliary fuel, to begin with, a clean fuel such as a distillate oil or gas and the cycle, illustrated in Fig. 15, is designed so that part of the firedamp is burnt in a temperature booster and the rest burnt as the combustion "air" for the auxiliary fuel.

This project is going ahead with the full collaboration of the National Coal Board. The Ministry is purchasing the plant and the National Coal Board is paying for its installation at a colliery, where it should begin to run towards the end of 1952.

There are two novelties in this kind of plant. One is the original notion of burning weak mixtures. The other is the physical

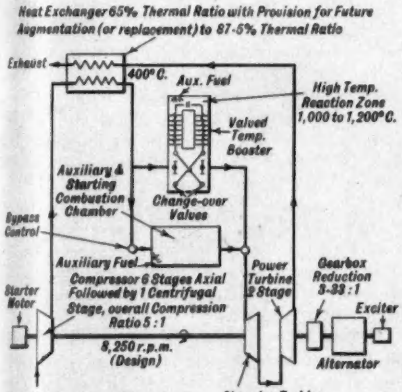

Heat Exchanger 65% Thermal Ratio with Provision for Future Augmentation (or replacement) to 87·5% Thermal Ratio
Exhaust
400° C.
Aux. Fuel
High Temp. Reaction Zone 1,000 to 1,200° C.
Valved Temp. Booster
Auxiliary & Starting Combustion Chamber
Change-over Valves
Bypass Control
Auxiliary Fuel
Compressor 6 Stages Axial Followed by 1 Centrifugal Stage, overall Compression Ratio 5 : 1
Power Turbine 2 Stage
Gearbox Reduction 3-33 : 1
Starter Motor
Exciter
8,250 r.p.m. (Design)
Alternator
From Colliery Upcast Through Filters etc. (0·5 to 1% Methane by Volume, i.e. Approx. 5 to 10 B. Th. U. per cub. ft.)
Charging Turbine 2 Stages, Exp. Ratio Approx. 2·7 : 1

FIG. 15—*Cycle Diagram of 2000kW English Electric Firedamp-Burning Gas Turbine Set*

means of doing it—the temperature booster. This device demands, in consequence, some detailed attention.

A pilot temperature booster to handle 1 lb of air per second at 5 atmospheres pressure has been constructed and is shown in Fig. 16. This is essentially a ceramic regenerator with pneumatically operated mushroom type valves at the low-temperature ends and with a bridging reaction chamber across the high-temperature ends. The ceramic matrix in each leg is composed of layers of thin high-alumina slats packed on edge with narrow gas passages. One layer is seen in Fig. 17. In the next layer, the slats lie at 60 deg. to those in the first layer. These two arrangements alternate. The firedamp-containing air is admitted through the appropriate valve to the bottom of a leg and proceeds upwards, receiving heat from the ceramic matrix until its temperature is raised to the point at which oxidation of the methane proceeds rapidly. The heat exchanger is so designed that this temperature is reached just before the top of the matrix. The oxidation is completed in the reaction chamber and the air and gas products are raised in temperature a further amount (depending on the original methane content and the proportion consumed). These hot gases then pass down through the other leg, giving up heat *en route* to the ceramic matrix before passing out through the gas valve diagonally opposite to that used for admission. After these conditions have continued for a time it will be appreciated that one matrix (on the "air" side) will be cooled and the other matrix (on the "gas" side) heated. Before this cooling and heating has proceeded too far, the flow direction is reversed (by opening the closed valves and closing the open valves). After the appropriate interval, the flow is reversed again, and so on, so that the temperature booster operates as a regenerator with a temperature difference produced by the reaction to "drive" the heat exchanger.

The Gasification of Coal

Of the several ways of obtaining gas from coal there are two which have long been the subject of discussion, speculation and preliminary experiment. I refer to "underground" gasification and "total" gasification. Neither of these terms defines a single process; there are many ways of doing each. Each, however, defines a single broad idea, an idea which needs most careful examination because if it were successfully translated into practice it could have tremendous consequences. Fresh consideration has therefore been given both to underground gasification and total gasification, and I propose to give some account of recent developments.

Underground Gasification.—The idea of obtaining energy from coal without first mining it is not new (Jolley and Booth, 1945; Lloyd Jones, 1950), but practical progress has been confined to the last twenty years. Since 1931 there has been a great deal of work done in Russia (Jolley and Booth, 1945; Lloyd Jones, 1950), but it is difficult to assess the scale of operation and the progress made. In western countries, there has been considerable experimental activity since the 1939–45 war. Interesting data have been obtained in Belgium, the United States, Italy and French Morocco as well as in Great Britain.

The energy obtained from underground gasification is the result of a producer gas reaction accompanied by the distillation of volatiles and, usually, some water-gas reaction. The product is generally a combustible gas of low calorific value, but high temperature. If it can be produced economically, we aim to use it, on the site, as the fuel for electricity generating machinery. The other possibilities of distributing it as town's gas or using it as a synthesis gas for liquid fuel manufacture are not yet being seriously considered here; their practicability depends upon greatly improving the quality of the gas produced at an economic cost.

The work done here has so far been different in two important ways from the work in the other western countries. In the first place, our idea has been to try to make use of coal which would not be mined because of its poor quality or for some other reason which made bringing it to the surface uneconomic. Britain has hundreds, possibly thousands, of millions of tons of such coal. Secondly, in these other countries, the systems have been made by mining, and the objective has generally been the gasification of that portion of a sloping seam lying above a horizontally mined gallery. With a considerable effort being applied elsewhere to this line of attack, we have devoted attention here to methods which do not involve mining, methods of creating underground systems which can be worked from the surface. Whether this approach will prove to be more or less economical than the alternative being examined in the other countries will not be known for some time to come. Close liaison is being kept with the work in the United States, Belgium and France, and it may be necessary later to try under British conditions the methods being investigated in those countries before a conclusion can be reached on the economics of underground gasification of British coals.

I must, indeed, emphasise that the objective of the present British work is to discover whether underground gasification could be an economic commercial operation in Great Britain. Preliminary assessments, which included appreciation of foreign work, suggested that work in the field on an experimental scale, designed to provide data on which a dependable assessment of the economic prospects could be made, was justifiable and so the present programme was put in hand in 1949.

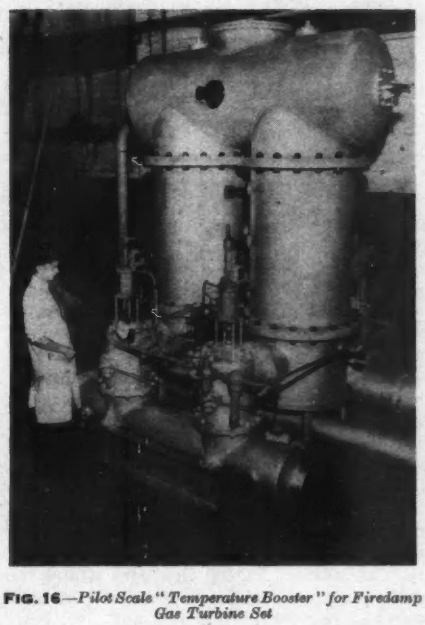


FIG. 16—*Pilot Scale "Temperature Booster" for Firedamp Gas Turbine Set*

Given the approach to underground gasification which I have indicated, there were at the outset two main lines of study—the investigation of the gasification process and the quite separate investigation of methods of creating the system. These studies would be followed by consideration of the use of the energy. As, however, for the study of the gasification process in the field the creation of a system was an essential preliminary, a method was adopted which, though of considerable intrinsic interest, was recognised from the outset as of limited applicability. This method, involving horizontal drilling, was particularly suitable for the site at Newman Spinney, near Chesterfield, where work was started.

The first system was made by drilling two vertical holes, of 4in diameter and 50ft apart, from high ground down to a wet banded coal seam about 75ft below the

* Institution of Mechanical Engineers. Thomas Hawksley Lecture, Abstract. November 16th.

† Chief Scientist, Ministry of Fuel and Power.

‡ "... to develop a gas turbine which burns the upcast gas together with an auxiliary fuel more tractable than coal fines."

surface. Opencast operations had produced an exposed face at a low level nearby, from which a roughly horizontal hole could be drilled to intersect in the seam with the verticals. This drilling work, so easily dismissed in a few words in this brief account, produced numerous problems of interest to engineers quite apart from their relationship to underground gasification (Plane, 1951). In particular, new techniques for effecting intersection between vertical and horizontal drillings had to be developed.

The vertical and horizontal drillings formed a U-tube with its base in the coal. In July, 1950, the coal was ignited with Calor gas and air was pumped down one vertical in such measure that the gasification reaction was maintained. The system, shown diagrammatically in Fig. 18, continued to produce gas until March, 1951, when it was closed down.

Details of these early trials have been given by Masterman (1951), who has been in charge of the work since an effective start was made in August, 1949, and by Plane (1951). For the first ten weeks of gasification the gas quality was maintained without any difficulty at an average of about 80 B.Th.U. per cubic foot, the only encouragement needed being occasional reversal of the direction of air flow when undue increase in upcast temperature or drop in gas quality suggested it. In other words, each vertical hole was in turn upcast and downtake. As the burnt-out space became wider, the tendency for some of the air to miss contact with the walls became evident in a lowering of the gas quality. Some encouraging experiments were done to overcome this in which air was introduced at the side of the passage from an additional vertical. By this means, the quality of the gas was partly restored. The effects of variation in the frequency of flow reversal and in the rate of air supply were examined and at one stage steam was introduced to see whether it would improve the gas quality. Its effect was, however, masked by the presence of a great deal of water in the seam.

During the initial ten-week period when the production of gas was most satisfactory, over 100 tons of coal were gasified with a total thermal yield of about 67 per cent, made up of some 49 per cent as combustible gas, 11 per cent as sensible heat, and 7 per cent as steam. During this period, and the subsequent periods of deterioration and partial recovery, much valuable basic information was obtained. It was possible to begin to make elementary economic calculations which suggested the possibility of producing the gas in a full-scale system at between 1d. and 2d. per therm, rough figures substantially less than the probable revenue the gas could earn as a power producer—2½d. to 3d. per therm.

While these first trials of the combustion and gasification processes were running, a great deal of thought was being given to the problem of finding a more generally applicable way of making the underground system. The idea of a "mechanical mole," which had been investigated in Belgium, was seriously considered and the methods under development in oil fields for drilling curved holes were examined. The possibility of directional explosive charges was not overlooked. The most interesting possibility, however, seemed to be to make a passage by the application of pressure, which, it was suggested, would either open up natural fissures in the coal or lift the overburden and cause a crack above, below, or in the seam.

The first experiment to test this was with compressed air and was on a modest scale, the two verticals being only 33ft apart. Naturally, the compressed air tended to diffuse evenly round the downtake, but when the pressure exceeded that of the overburden—at about 100 lb per square inch—the presence of the upcast made itself felt and it began to deliver about 20 per cent of the air supplied. Ignition was achieved

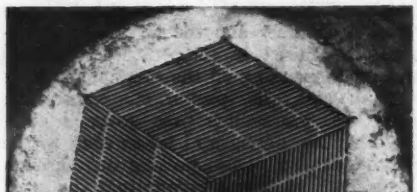
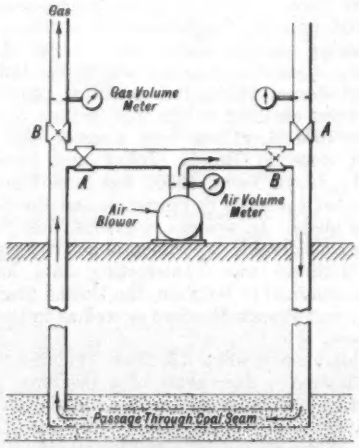


FIG. 17—*Layer of Matrix in Temperature Booster*

at this pressure by means of hydrogen, and gasification was maintained for some three weeks, by which time a drop in the required pressure showed that a connecting channel had been burnt through between the boreholes. Thereafter gas production continued at the usual low pressure. The three weeks at high pressure is obviously inconvenient and expensive (and would be more so with the much larger channels which would be required in practice), and our effort is being directed to pressure techniques in which this initial delay does not occur.

The initial work at Newman Spinney, though encouraging and full of interest,



Reversal of flow is obtained by opening valves *A* and closing valves *B*. All connections for gas sampling, water cooling, &c., are omitted.

FIG. 18—*Simplified Scheme of Underground Gasification Experiments*

naturally left some important questions unanswered. The first is—how favourable or unfavourable is the site? Certainly the coal is poor in quality. It is half dirt, wet, containing 9 per cent sulphur and is lying in thin layers. Clearly experience with coal of different kinds is needed before a true assessment can be made. This is one of the reasons for seeking additional sites for experiment and trials are in preparation at the first of these, in Worcestershire, where the coal and geological formation are substantially different from those at Newman Spinney. Another obvious problem was to find the optimum spacing of verticals and the best geometrical arrangements. Trials have begun at Newman Spinney with a second system, made by horizontal drilling, with verticals 75ft apart, which will throw some light on this. Trials on the same site are also being extended to a seam at 200ft depth. In this case, we hope to establish the system by high pressure and to operate on a larger scale than has yet been attempted in Great Britain.

The experiments so far have been confined to the study of the gasification process and the making of systems in flat seams. Utilisation of the gas produced does not appear to us to present serious difficulty, but is being carefully studied as part of the economic survey as we learn more about the characteristics of the gas and the cost of getting it. There is no present intention of trying to make gas for domestic purposes or synthesis purposes; the aim is industrial gas which may be burned in power stations on the underground gasification site.

Until the end of 1950 the underground gasification field experiments were run entirely by the Ministry of Fuel and Power, with the advice of a scientific committee and the help of the National Coal Board. The interest of the Board in the work has resulted in their contributing directly in 1951 to its support with finance, staff and facilities.

It is hoped that in the next few months the work will have given enough information for an economic assessment to be made. If this is favourable, we should hope to check it by means of a pilot scale system. Given success at that stage, it might be right to incur the heavy expense of a full-scale scheme. The foundations must be well and truly laid, however, before such a step is taken; a great deal remains to be learned. But the possible prize—a large-scale addition to our national fuel resources—is so great that continued experiment, if necessary over a long period, appears to me to be fully justified.

"*Total*" *Gasification*.—By "total" gasification is meant the conversion of coal into gas with such completeness that the only other product is ash. In this sense, total gasification has long been practised, not only in the form of the gas producer process, but as the gasworks process of carbonisation with water-gas generation from the resultant coke. Other processes have been developed, notably in Germany, but only for brown coals. These and other methods as applied to our own coals have been debated for some years, but a fresh review was made in the Ministry towards the end of 1949, which resulted in the sketch of an attractive picture, in which gasification of a wide range of the cheaper coals, near to their source of production, was associated with high-pressure transmission of the gas to the points of consumption. The subject was considered by the Scientific Advisory Council, who agreed with the need for more detailed investigation, and in 1950 a committee was formed under the chairmanship of Dr. F. A. Williams to examine the subject of gasification and its associated problems and to report on what methods it thought most promising for a concentrated effort to evolve a commercial process.

The committee made an interim report in February, 1951, in which it advocated the adoption of the hydrogenation method of the Gas Research Board, integrated with the generation of electrical power from the hot gases and carbon residues from the gasification process. In other words, the committee had added an important feature to the picture—the idea, in the interests of

maximum economy, of abandoning total gasification in favour of integrated gas and electricity production.

The suggested scheme permitted the use of cheap non-caking coals. It involved the treatment of coal with hydrogen under a pressure in the range 25–50 atmospheres at a temperature of about 900 deg. Cent. (1650 deg. Fah.). It was estimated that the gas could have a calorific value well above 500 B.Th.U. per cubic foot if desired. Being generated under pressure, the gas would be particularly suitable for transmission along high-pressure pipe-lines in a manner similar to that used for natural gas in the United States and for coke-oven gas in Germany, and, in general, the picture of a high-pressure country-wide gas grid, based on gasification of the cheaper coals in the coalfields, was given greater definition.

This lecture is a progress report. In the cases of some of the projects discussed, the "hardware" stage has been reached. In others, it is well advanced. In this case, we are only near the end of the "talking" stage. I have thought it worth while discussing even this early stage, however, as the matter is one of prime importance. Not only does the scheme of high-pressure generation in the coalfields in association with a high-pressure grid transmission system represent a major change in the country's organisation, but the three great fuel and power industries —coal, gas and electricity—are also all involved in it. Such a scheme must of necessity be considered with the greatest care, and only now are we nearing the point of an expanded experimental effort. The committee I referred to seem to have taken the matter as far as it can go without experiment on a considerable scale.

At this stage, the major uncertainty lies in the choice of the method to be used to prepare the hydrogen rich gas demanded by the hydrogenation stage. Part of the residue from this stage could be employed and for this several methods, including the use of oxygen, are available. An alternative is to crack with steam part of the methane produced by hydrogenation. The committee has not been able to select a preferred method and my own view is that two or more will have to be tried in pilot plants before the best solution is found.

[The lecture also included a description of the Royal Festival Hall heat pump. It concluded with sections on the use of peat, the development of the centrifugal compressor, wind power and other sources of energy.]

The Iron and Steel Institute

No. II—(*Continued from page 701, November 30th*)

THE next papers to be taken were the following :—

METALLOGRAPHY OF CARBON IN SILICON-IRON ALLOYS CONTAINING 4 PER CENT SILICON

By E. D. Harry, B.Sc., A.I.M.

Synopsis

In the first part of the paper an account is given of the mode of occurrence of carbon in 4·0 per cent silicon-iron alloys used for the manufacture of transformer sheets. The account starts with the sheet bar, which may contain 0·050–0·10 per cent of carbon, and ends with the finished sheet, which may have been annealed at temperatures ranging from 750–1150 deg. Cent., and in which the carbon content may vary from below the limit of solid solubility to 0·030 per cent.

Mention is made of an effect involving carbon segregation, which has been observed in this material. Pick-up of carbon from the furnace atmosphere during annealing is also described.

The second part of the paper deals with the constitution of the carbide phase in these silicon-irons, and it is shown that this phase is duplex in structure, consisting of the ordinary iron-carbide, Fe_3C, and what is believed to be an iron-silicon-carbon compound, the two carbides appearing to form a eutectoid.

THE VARIATION IN ELECTRICAL PROPERTIES OF SILICON-IRON TRANSFORMER SHEET: A STATISTICAL ANALYSIS OF DATA FROM A SINGLE CAST

By S. Rushton, M.A., B.Sc., D.I.C., and D. R. G. Davies, B.Sc., A.I.M.

Synopsis

This study of the variation in iron-loss values of sheets produced from a single cast of silicon-iron transformer sheet is based on 264 values from eleven ingots of the cast, and on iron-loss values of all the sheets produced from one particular ingot. The statistical technique of analysis of variance has been used to show the contributions to the total variation among these values due to differences between ingots, variation due to different positions in an ingot, and variation due to differences in the position of the sheet in the pack at the sheet rolling stage. The effect of a second anneal has been studied, using the analysis of covariance technique. Causes of the variation in iron losses are discussed.

Discussion

Dr. E. V. Riley (Staveley Iron and Chemical Company, Ltd.): The second paper, by Rushton and Davies, is rather outside my line of country, but I have been very interested by one or two points in it. First of all, I should like to say that the treatment which these authors have given to a works problem is worthy of note. This is a thoroughly practical paper, and there are many other operations in works which would repay study in this fashion. I was interested in the variation reported in the ingot. It always seems to me that steelmakers have considerable difficulty in casting ingots, and in this instance I wondered why the steelmakers want to make an ingot. After all, they are going to make out of it transformer sheet, a rolled sheet product, so why not make it in sheet form to start with? I suggest that a possible way of removing the non-metallics which appear to be so troublesome in this industry is to cast the steel centrifugally into fairly large cylinders, which are then split longitudinally, opened out under a press, squeezed down and both sides of the sheet machined. The part which has been on the inside of the cylinder will then contain the non-metallics which are not desired, and these can be removed by machining. You can then reheat and carry on rolling in sheet form. This is simply a development of the blowing of ordinary window glass. The glass blower blows a cylinder, opens it out and then presses it flat. Perhaps this little idea may be useful for getting over some of the difficulties which have been experienced with transformer sheet.

The President: Dr. Riley has thrown his hat into the ring by suggesting a new method of casting the steel. That should give many of us something to think about, and should give the Engineers' Group of this Institute something to think about, too!

Mr. A. D. Grace (Guest Keen Nettlefold Research Laboratories): I am not a metallurgist, so that I have only a few points to raise on the statistical angles of the paper by Rushton and Davies. In taking the test of watts loss I wonder whether any allowance was made because of variation in the gauge of individual sheets. We have found that, with the ordinary 014 gauge hot-rolled sheet, there can be variations which will cause a difference in the watts loss of something like ±0·02W/lb. That, of course, is purely due to the eddy current component, which, as you know, is more or less proportional to the square of the thickness. If that has not been taken into account it may account for some of the extreme variance found between sheets in a pack, but in my experience it does not account for anything like the whole variation, so that I do not think that it alters the conclusion reached. I should like to mention one or two small points which do not mean very much. In conclusion, the authors say: "The two significant factors which contributed equally to the variation were: differences between positions in the ingots and differences between positions in the sheet rolling pack." I raise the question of the equality there because although the mean squares in the analysis of variance are very nearly the same figure, if you break it down into the components of variation you find that the ingot variation accounts for something like 38·5 per cent and the position in the pack for about 12·6 per cent, and there is a residual of about 48·9 per cent. I do not know whether the authors will agree with that or not.

Mr. H. H. Stanley (Steel Company of Wales (Lysaght Works), Ltd.): I think that this is the first occasion on which papers dealing with 4 per cent silicon transformer steel have been put before the Institute for discussion. This, I believe, marks a very great change in the industry. The paper by Rushton and Davies shows that, with the process which they describe, very wide variations in the product result and this, I think, suggests that the process is very difficult to control, so that manufacturers who have found a way of getting what they think is rather better control of their process are very reluctant to publish the "know-how" of the operation of their process. I think, therefore, that Mr. Davies's employers, Messrs. Richard Thomas and Baldwins, are to be commended on the fact that they have given permission to publish work of this type, because I know that it does involve the cutting up of a very large number of expensive sheets and the planning and carrying out of the experiments and testing must have added considerably to the cost. It is all the more unfortunate, I think, that the work should have been confined entirely, at least as published in this paper, to a statistical study. Having used such large amounts of precious material, it is a pity that some metallurgical tests were not carried out or, if they were carried out, published, so that we could judge what relationship there is between the theories, the hypotheses, on decarburisation and so on, which are put forward and the actual results found in the sheet.

I am not a statistician and therefore my remarks will have to be confined to the metallurgical aspects of the paper. The authors give the analysis of a cast as 0·05 per cent carbon and the sheets range from 0·035 per cent to as high as 0·048 per cent carbon. I find this very difficult indeed to believe. I do not think that it is possible to keep carbon in sheets which are hot rolled in packs; it tumbles out and if you begin with 0·05 per cent you will end up with 0·02 per cent. If the hypothesis of decarburisation is the explanation of some of the variations I find it very difficult to believe that there can be the same carbon content in a sample giving a core loss of 0·94W/kg and in another giving 1·4W/kg. I think that it indicates that the method

of analysis is somewhat seriously at fault. In all my experience I have never seen a core loss of 0·94W/kg with a carbon higher than 0·015–0·02 per cent. Coming to the variation due to position in the pack, this is a very interesting subject. It is one on which I have, on behalf of my employers, carried out tests over a number of years. We have found wide variations within the pack. Sometimes the variation is considerable and sometimes it is not very great, but it seems to be a characteristic of the mill, or rather the mill furnace. We find that one particular unit will give one pattern in the relationship between core loss and position and another mill another.

One striking thing about these data is the wide variation over a cast. This seems to be abnormally large and I do not think that it is representative; it is much larger than one would expect. It would have been very interesting if some indication had been given of the origin of the extreme sheets, i.e., those giving very good core losses and those giving very bad ones, and if the authors had shown which sheet in the pack they came from.

Dr. M. L. Becker (British Iron and Steel Research Association): I feel that there are two phases present at the annealing temperatures used by Mr. Harry. If that is the case we must consider that those two phases will have different compositions. If there is one phase which is ferrite, no doubt containing a high percentage of silicon and, I expect, a low percentage of carbon, the other is the austenite, containing a relatively large percentage of carbon and probably less silicon. On that point I should like to ask the author whether he has any evidence that the silicon content of some areas in his specimens is less than in the others. If such an alloy is then cooled, even quite slowly, I should not expect this two-phase condition to disappear during cooling. Once the carbon and possibly the silicon have diffused to a considerable extent, it is unnatural to expect that they will get away from each other just in cooling. The structures are therefore to be interpreted, I think, from the point of view that there are two separate zones present in the same alloy and, accordingly, the structure of the two separate zones will be different.

Mr. R. Rawlings (English Electric Company, Ltd., Nelson Research Laboratories); Dr. Riley mentioned the use of centrifugal casting. This has already been seriously considered, but not for long. Very little is known about the effect of inclusions, but what is known theoretically is that there is a certain optimum size of inclusion which has the greatest effect and this size is in fact very low. That has been proved with iron carbide, using iron carbide as an inclusion, and it has been precipitated at low temperatures in different sizes of spheres, and there has been shown to be an optimum size. Centrifugal casting would probably not remove the inclusions of that size.

Mr. H. Brooke Freeman (John Summers and Sons, Ltd.): I suggest to Mr. Davies that he has not given rolling details sufficiently fully to be able to check, next time he makes some of these experiments, what differences he will find if he changes his method of rolling slightly. In rolling these silicon sheets the first operation is to take the 15 lb bar and break it down with three passes in the mill and then to match those breakdowns and give them another two or three passes, and then double. I should like to ask whether in this case the doubler separated them and put them top to bottom instead of simply rolling them out and doubling them over; did he change them so as to bring two outsides inside? The next thing is the running over, the operation following the reheating of the doubled pack. When you double, the sheets are dealt with so that the two outside surfaces come together and so do the two insides. The pack is pushed into the annealing furnace with the doubled end first and the furnace man turns it up along the side so that it lies along the side wall. I should like to ask the authors how many packs they ran over at a time, because it will be found that the number of packs makes a big difference in the heating or the soaking that one can get for these sheets. Do they roll eight or twelve or sixteen? Sixteen is quite a usual number to roll in sheet works but we found that it was far better to roll eight; in other words, we had double the number of running-over furnaces and put eight in a furnace and no more. These packs are turned up alongside the wall as they are put in and they are gradually turned down, one after the other, for the furnace man to try to get them evenly heated. You will find that there is a big difference in the watts loss according to whether you are rolling eight packs or twelve or sixteen, and the secret seems to be to keep the temperature up all the time. That is another thing which we tried to do. In the running over, which is the next operation, you take the pack of four and give it one pass through the rolls, and you have the eight sheets. We tried cutting the ends off and changing the sheets instead of simply doubling them in the middle and bringing them back on themselves, and that will affect the watts loss. We tried these tricks with the low silicon, the 1 per cent. We did not roll much of the 4 per cent; it was 3¾ per cent in my day. We found a big variation in the watts loss, according to the treatment adopted in the rolling of the sheets.

The President: The last two papers have dealt with a very important subject, which is of real importance in the economics of this country. Three or four years ago, in one of my capacities then, I was concerned with the shortage of supply of these high silicon sheets and I remember the difficulties which existed in getting not merely quantity but quality. In that direction there have no doubt been substantial improvements since that time, but in those days there were considerable difficulties in getting anything like collaboration between the relatively few companies that were producing these sheets. I was glad to hear Mr. Stanley draw attention to the improvement in that position represented by these papers. I hope that they mark the beginning of some publicity on the technical problems involved in producing these sheets. I think that the discussion which we have had to-day may have helped to bring some new factors into the minds of any representatives of the manufacturers of silicon sheets who have been here. I for one believe that progress in quality can best be made in this way, and it is a great satisfaction to us to know that at last the ice has been broken on this question of publicity about the techniques and the very many intricate points of technique involved in the production of these sheets. I thank the companies who have rendered such good service in this way.

(To be continued)

TESTS AND MEASUREMENTS OF GEARS.—A recent test pamphlet, No. 9, of the National Physical Laboratory describes and gives a schedule of fees for tests and measurements on gears, gear-cutting tools, gear hobbing machines, and spline and serration gauges.

A Statistical Approach to the Replacement of Street Lamp Bulbs

ON Wednesday, November 28th, a paper entitled "Electricity Supply—A Statistical Approach to Some Particular Problems" was presented by Mr. R. B. Rowson before the Institution of Electrical Engineers, in London. The paper called attention to the help which statistical technique can give to the commercial and engineering sides of electricity supply. To illustrate the technique the paper showed how statistical methods could be used, for example, to assess generating plant liability, to forecast future load demands and the effect of temperature, to estimate the seriousness

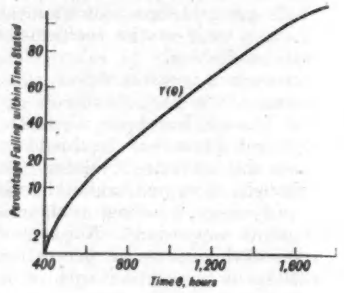


FIG. 1

of trouble due to lightning strokes and to determine the effect of tariff changes on the consumer.

Statistical methods can also be used to help authorities responsible for street lighting installations to arrange an economical programme for replacement of the lamp bulbs. This problem is considered in the following abstract of Mr. Rowson's paper.

It is well known that electric lamps are sold on the basis of a specification under which, amongst other things, their mean life is about 1000 hours. As with most products, if one took a sample of, say, 100 bulbs from a large batch, one might find that one bulb failed at 100 hours, four at 500 hours, twenty at 1000 hours, &c.; there would be a variability, but, on the average, the hours per lamp would be about

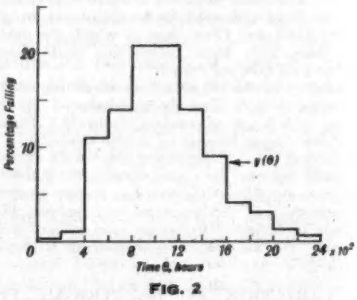


FIG. 2

1000. Now the authority responsible for a street lighting installation has, neglecting the question of efficiency (in terms of lumen/watt), at least two choices:

(*a*) To replace the bulbs when they fail (random replacement).

(*b*) To replace any bulb failing before T hours and to replace all bulbs at T hours, &c.

The piecemeal method usually involves high labour costs, but has the advantage of making use of the extra life above T hours, whereas the alternative method sacrifices this gain in favour of lower labour costs.

N. R. Campbell* has treated this problem in detail and a simplified version of his work follows. Fig. 1† shows a mortality curve, and Fig. 2† the corresponding frequency curve, of typical lamp life. Considering an installation of 100 lamps burning from dusk to dawn

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* "The Replacement of Perishable Members of a Continually Operating System," *Journal of Royal Statistical Society* (Supplement), 1941, 7, page 110.

† C. C. Paterson, "Uniformity as the Gauge of Quality," *Journal I.E.E.*, 1936, 79, page 655.

throughout the year, we might take replacement costs per replaced lamp as :

	s.	s.	s.
Lamp (depending on size)	3 ...	5 ...	15
Labour—regular replacement ...	5 ...	5 ...	5
Labour—random replacement ...	15 ...	15 ...	15

Now consider a period T at the end of which it might be decided to carry out regular replacement. Clearly, T should not exceed about 1100 hours (Fig. 1), as more than 50 per cent of the lamps would be subject to random replacement. On the other hand, if 600 hours were adopted, 90 per cent of the lamps would not complete their useful life, which is wasteful.

It must also be remembered that in a regular replacement scheme there is a chance that a lamp will have to be replaced twice before the time for the complete replacement of all lamps is reached. Thus, in a 100-lamp scheme, eleven lamps will, on the average, fail between 400 and 600 hours (Fig. 2). If $T=1000$, and it is assumed all the eleven bulbs failed at 600 hours, the replacements have to last 400 ($=T-\theta$) hours. From Fig. 1, 1 per cent fail in this period and will have to be replaced again. On this basis the accompanying table can be compiled.

It will be noted from this table that, for the periods considered, second failures may be neglected. The costs are thus :

Bulb cost	3s.	5s.	15s.
$T=1000$:			
Cost for failures before T hours (at "random" cost) ... ... 47 at	18s.	20s.	30s.
	£42	£47	£70
Cost for regular replacement 100 at	8s.	10s.	20s.
	£40	£50	£100
	£82	£97	£170
$T=800$:			
Cost for failures before T hours (at "random" cost) ... ... (26)	£23	£26	£39
Cost for regular replacement (100)	£40	£50	£100
	£63	£76	£139

Thus, if the average life is 1000 hours, the costs per 1000 hours are :

Lamp cost	3s.	5s.	15s.
Regular replacement :			
$T=1000$	£82	£97	£170
$T=800$	£79	£95	£174
Random replacement	£90	£100	£150

It thus appears that on a small scheme with low-wattage lamps and probably high random replacement costs, bulk replacement at, say, 800 hours is economic. With a large scheme and high-wattage lamps, however, where night staff would be on duty in any case, random replacement appears to be financially advantageous.

TABLE

θ	Percentage which failed in θ hours $=Y(\theta)$ (Fig. 1)	Percentage failing at θ hours $=y(\theta)$ (Fig. 2)	$T=1000$			$T=800$		
			$T-\theta$*	Percentage of first replacement failing $Y(T-\theta)$	$Y(T-\theta)\times y(\theta)$	$T-\theta$*	Percentage of first replacement failing $Y(T-\theta)$	$Y(T-\theta)\times y(\theta)$
Hours			Hours		Per cent	Hours		Per cent
0	0	0	1000	47	0	800	26	0
200	0·25	0·25	800	26	0·06	600	12	0·03
400	1	0·75	600	12	0·09	400	1	0·008
600	12	11	400	1	0·11	200	0·25	0·027
800	26	14	200	0·25	0·03	0	0	0
1000	47	21	0	0	0	—	—	—
1200	68	21	—	—	—	—	—	—
1400	82	14	—	—	—	—	—	—
Expectation of second failure					0·29			0·065
Expectation of first failure					47			26
					47·29			26·065

* Burning hours of first replacement.

Methods Used for Obtaining Pressure Diagrams*

A PRECISE knowledge of the gas pressure changes, which occur during the working cycle, is of great value in the study of reciprocating internal combustion engines. Thus, from a sufficiently accurate cylinder pressure diagram a large amount of information can be derived relating to such matters as the exchange of heat between the contents of the cylinder and the cylinder walls during the compression and expansion processes, the complex process of combustion, and the many actions which occur during the gas exchange process. Moreover, such a diagram enables the indicated horsepower to be assessed, so that a true measure of mechanical efficiency may be obtained, while the harmonic analysis of the resultant torque diagram gives the contribution of the gas pressure to the forces exciting torsional vibration.

LIMITATIONS OF VARIOUS INDICATING METHODS

The cathode-ray oscillograph type of engine indicator has proved to be a powerful aid in the qualitative study of the various phenomena associated with the working of internal combustion engines, but its versatility has tended to obscure its present limitations for quantitative work. The smallness of inertia effects, when a suitable pick-up diaphragm is used, makes possible the indication of pressure changes at very high frequencies, so that, for the study of detonation in petrol engines or combustion knock in diesel engines, this kind of equipment is by far the most suitable.

When a cylinder pressure diagram is required for such purposes as the determination of the harmonic components of the gas pressure torque or the indicated horsepower, the diagram obtained on the screen of the cathode-ray tube is of little value because the ordinates and abscissæ are not proportional to the pressure and time with the required degree of accuracy. The most suitable equipment in this respect, tested in the laboratory, is the Southern Instruments engine indicator, in which the proportionality of the tube deflection voltage to the pressure applied to the pick-up approaches the required accuracy. By using a drum type camera with this equipment the diagrams may be recorded against a time-base which is linear to the required degree of accuracy. The errors in the ordinates of the diagrams are partly due to lack of linearity in the response of the pick-up and associated circuits and partly to non-linear effects in the cathode-ray tube. The curvature of the screen of the tube introduces a serious error when the diagram is photographed. A promising development in the direction of greater accuracy of the pick-up and associated circuits is the Li catenary-diaphragm pick-up and amplifier[1].

The Farnboro' balanced pressure indicator is a promising alternative to the cathode-ray oscillograph with diaphragm type pick-up. The disc valve, which moves when pressure balance occurs, is arranged as a switch in the low tension circuit of a sparking coil and the switch contact surfaces, which are in communication with the combustion chamber, become fouled rapidly, especially in a diesel engine. The slightest deposition of carbon or lacquer produces irregular behaviour of the switch and a scatter of the points recorded on the diagram. The disc valve weighs 2·32 grammes ($\frac{1}{12}$oz), and it seems that an impact force is necessary to produce effective contact when some deposition has occurred. Even with the comparatively heavy valve provided sparking ceases entirely when a moderate carbon deposit has formed. The scatter is not due solely to carbon deposition because, when the contact surfaces are kept clean a considerable scatter of points occurs. When the standard 6V supply is used across the switch the effects of arcing on the contact surfaces are apparent and the disc valve may even become welded to one of the seats. The voltage cannot be reduced below 4V in the standard equipment, since sparking ceases below this value and this arcing probably accounts for the scatter which occurs even when the contact surfaces remain clean.

In a more precise technique, the Sunbury calibrating unit and point-by-point method developed by Stansfield[2], a small disc $\frac{1}{6}$in (4·76mm) in diameter, of the order of 0·020in (0·51mm) thick according to the application, is used as a disc valve and its movement is indicated by means of an electro-magnetic pick-up and an oscillograph. With this system there is apparently no scatter other than that due to actual variations of the pressure diagram from cycle to cycle. No arcing occurs, since the disc is not used as a contact breaker, and deposition of carbon has no effect on the accuracy of the indication of the moment of pressure balance until a very heavy deposit has formed.

As far as the majority of pressure diagrams is concerned, inertia effects are negligible. A typical disc valve, 0·018in (0·46mm) thick, weighs only 0·052 gramme ($\frac{1}{500}$oz) and has a mass per unit of exposed area less than a fifth of that of the Farnboro' disc valve. The disc valve cannot respond satisfactorily, however, to high frequency pressure oscillations.

Until recently the procedure employed has been as follows : the output of the Sunbury disc valve unit and the output of the degree scale pick-up unit are switched into the amplifier of a Sunbury engine indicator together so that a combined diagram is obtained. With a suitable setting of the time-base "spread" controls, the point at which the disc valve diagram breaks away from the degree scale may be read off to a fraction of a degree and errors in transferring measurements from the disc valve diagram to the degree scale are avoided. The combined diagrams are photographed on 35mm film, the frames of which are studied in a microfilm reader and the points obtained plotted directly. This procedure has the advantage that the engine running time taken to obtain the necessary records is reduced to a minimum and the records analysed in quiet surroundings. The disadvantage of this method is the long time taken to produce a diagram, which may take three hours to produce if the pressure undergoes a large number of fluctuations during a single cycle.

RECENT DEVELOPMENTS

A need was apparent of an automatic means of plotting the timing indications produced by the Sunbury disc valve unit against the values of the pressure applied to the unit. A truly linear time-base was essential and a drum driven by the engine appeared the most certain way of obtaining this and this led to further consideration of the Farnboro' indicator. The air cylinder, springs and linkage system of the Farnboro' were capable of giving a movement proportional to pressure with a high degree of accuracy and the spark method of recording the instant of pressure balance appeared satisfactory. The problem was to control the sparks for the Farnboro' indicator

* "Methods Used at the B.I.C.E.R.A. Laboratory for Obtaining Pressure Diagrams". Research Report by the British Internal Combustion Engine Research Association, Slough, Bucks. Abstract.

by means of the Sunbury disc valve unit. It was proposed that the electromotive force produced by the Sunbury disc valve unit should be applied, after amplifications, to the grid of a thyratron valve used to release pulses of current into the primary winding of the sparking coil.

A satisfactory circuit was found and developed. All the components necessary to couple the Sunbury disc valve unit with the Farnboro' recording unit were housed in a case measuring 13½in by 9in by 10in (34cm by 23cm by 25cm), which may be seen in Fig. 1, and they were connected as shown in the circuit diagram reproduced in the report. The output of the disc valve unit is amplified by a two-stage resistance-capacity coupled amplifier and then passed to the primary winding of a Class B transformer. The secondary of this transformer is centre-tapped and the output is applied to the grids of two thyratrons. Flow of current in either direction in the primary of the transformer, resulting from movement of the disc valve in either direction, raises the grid voltage of one or the other of the two thyratrons above the critical control voltage, thereby discharging a condenser, the discharge current passing through the primary of a sparking coil.

One end of the secondary winding of the sparking coil is earthed in the normal manner and the other is connected to the Farnboro' recording unit. The circuit also embodies refinements such as decoupling between the two stages of the amplifier, means for adjusting the control voltages of the thyratron, and a thermal delay switch to prevent high anode voltage being applied to either thyratron before the cathode temperature has been raised sufficiently by the heater. A suitable high tension unit, comprising transformer, valve rectifier and smoothing devices, is incorporated to permit operation from 230V, 50 c/s a.c. mains.

Examples of the diagrams produced by the new system and the corresponding diagrams given by the normal Farnboro' equipment are included in the report. In order to obtain the best possible diagrams by the Farnboro' method, several special precautions were taken

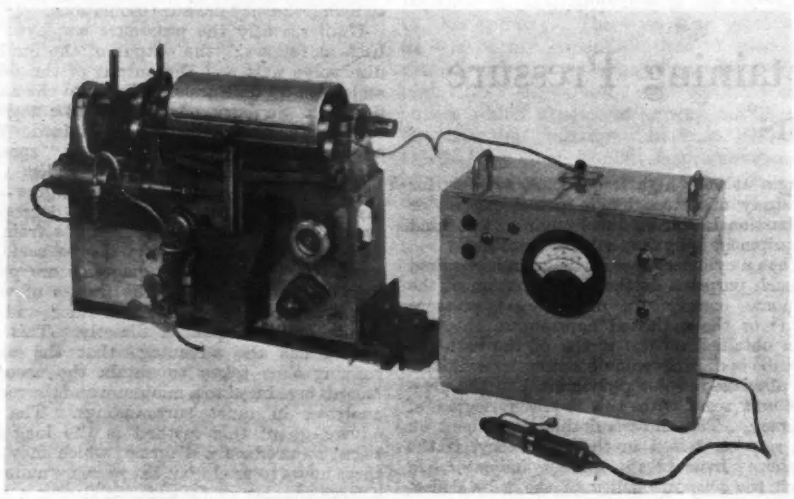

FIG. 1—ENGINE PRESSURE INDICATING APPARATUS

and, for the low pressure diagrams, the specially constructed large air piston and cylinder shown in the drawing (Fig. 2) was used with both methods to minimise frictional effects.

The diagrams produced by the new method were checked by the points obtained by the normal Sunbury disc valve method using the cathode-ray oscillograph and no significant discrepancies were found. The pressure calibration lines on the diagrams were produced by a method similar to that which has been used in the past with the normal Farnboro' indicator. A suitable steady pressure measured by an accurate Bourdon gauge or liquid manometer is applied to the piston of the indicator in the normal manner, and as the drum rotates a succession of sparks is passed through the paper, producing a straight line across the diagram. This process is repeated at a suitable number of pressures covering the pressure range of the diagram. With the normal Farnboro' indicator a simple buzzer is connected in place of the disc valve unit to make and break the primary current of the sparking coil. In the B.I.C.E.R.A. system, by the operation of a switch on the thryatron control unit, a signal is taken from the 50 c/s main and applied to the circuit in place of the signal from the disc valve.

Accurate marking of the top dead centre lines or other engine timing marks on the diagram is essential, since small errors produce large errors in the derived torque curves and the values obtained for indicated horsepowers.

When the B.I.C.E.R.A. diagrams shown in the report were recorded, the top dead centre lines were sparked on while the engine was running, using a contact breaker on the flywheel to pass a signal to the thyratron control unit precisely at the top dead centre position of the engine. This made due allowance for the delay between the application of a sufficient voltage to the thyratron control unit and the passage of the spark and the line thus obtained coincided with that sparked with the engine at rest. Using this timing line, the diagrams were found to be in agreement with points obtained with the same disc valve unit by the point-by-point method, the degree scale being set, in accordance with the latest recommendation, with the 90 deg. slot symmetrically disposed about the centre-line of the pole-piece of the degree marker pick-up. It was concluded that the method gave the same accuracy as the Sunbury point-by-point method, so that the object of the work had been achieved.

In order to permit still more accurate determinations and to cater for the indication of engines running at speeds higher than the 1200 r.p.m. used, tests were made to measure the actual period of delay. The delay period between the application of a sufficient voltage to the grid of the thyratron and the passage of the spark was first measured by arranging a contact breaker driven by an electric motor to apply an ample voltage from a battery to the thyratron control unit. The same signal was passed to a cathode-ray oscillograph and on the trace produced was superimposed a signal obtained by induction from the sparks produced by the control unit. The interval between these signals was found to be 0·016 millisecond, corresponding to 0·11 deg. of crank angle at 1200 r.p.m. This accounted for the apparent coincidence of the top dead centre lines obtained statically and by the contact breaker on the flywheel. It is clear that in addition to this delay, there must be some delay before the disc valve unit produces sufficient voltage to operate the thyratron. To measure the total

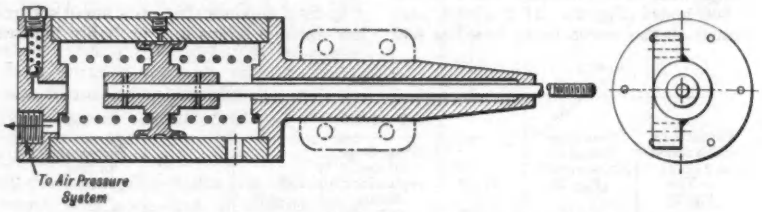

FIG. 2—AIR PISTON AND CYLINDER FOR LOW PRESSURE DIAGRAMS

delay, the amplified output of the Sunbury balanced disc valve unit was applied without integration, to a cathode-ray oscillograph using a very large "spread" of the time-base. The output of the pick-up, which was mounted in an engine cylinder, was also applied in the normal way to the thyratron control unit operating the Farnboro' recording unit. A signal obtained by induction from the sparks of the Farnboro' was superimposed on the input from the pick-up to the oscillograph. The diagram thus produced showed the initial movement of the disc valve and then an almost vertical deflection of the spot due to the signal from the spark. The distance between the first perceptible rise of the disc valve lift diagram away from its base and the spark line, was taken as a measure of the total delay period. The normal degree scale obtained with the Sunbury time-sweep unit driven by the engine was used as a time-base.

At rates of pressure change above 50 lb per square inch per millisecond, the total delay time may be taken as constant at 0·124 millisecond which corresponds to 0·89 deg. of crank angle at 1200 r.p.m.

Between 50 lb per square inch per millisecond and a pressure change rate close to zero, the delay time rises from 0·124 to 0·021 millisecond, i.e., from 0·89 deg. to 1·51 deg. of crank angle at 1200 r.p.m.

On the low pressure diagrams the maximum rates of pressure change are of the order of 1 lb per square inch per millisecond, so that the time delay for all points is close to 0·2 millisecond, 1·44 deg. at 1200 r.p.m. In most other cases it will be sufficient to apply a common correction to all points on the diagram by drawing a new T.D.C. line alongside the line sparked with the engine stationary at T.D.C.

For reference purposes the combination of the Sunbury balanced disc valve unit, the control unit and the Farnboro' indicator has been termed "B.I.C.E.R.A. Engine Indicating System 1."

A paper[3] was published describing the development in the Department of Mechanical Engineering, University of Witwatersrand, of a modified form of Farnboro' indicator, in which the free disc valve is replaced by a thin diaphragm. The moment of pressure balance is indicated by the breaking of contact between a central contact point and the diaphragm. The thin diaphragm is supported at the extreme positions of movement by backing plates and the contact point is adjusted so that it just makes contact with the diaphragm when this is resting against the backing plate on the side to which the steady pressure is applied.

To avoid pitting of the contact surfaces, a small current is used and the voltage changes

produced by the action of the contact breaker are applied to the grid of a thyratron valve controlling the sparking coil. An indicator which embodies the same features has been developed by the Massachusetts Institute of Technology and is manufactured by the American Instrument Company[4]. This modification overcomes the two main defects of the Farnboro' indicator, but introduces other serious difficulties. A description of the action of a balanced diaphragm unit and indications of the sources of error, are given in an early report by Dickinson and Newell of the Bureau of Standards[5]. It is extremely difficult to arrange a thin clamped diaphragm so that it is truly flat. Even if the diaphragm surfaces are perfect planes before clamping, the process of clamping produces radial compression, tending to make the diaphragm bulge, and in this manner a large biasing force may be produced. Even if the diaphragm is clamped initially so that it is flat and exerts no force on the backing plate, and at the same time the contact point is adjusted so that it makes contact with the diaphragm but exerts no force on it, it is unlikely that these conditions will be maintained when the unit is screwed into a cylinder-head and heated. It should be noted that the sparking of calibration lines across the pressure diagram, at a number of known applied pressures, merely calibrates the air piston springs and linkage system, whilst the operation of the contact breaker or its equivalent at the true moment of pressure balance is taken for granted in all such systems. The free disc of the Sunbury unit moves at the true moment of pressure balance because only the gas forces act upon it. It is free of the objections of the original Farnboro' unit and those of the diaphragm type modification.

A further advantage of the use of a balanced disc valve as opposed to a diaphragm is that it makes possible the construction of a very small pick-up unit. A suitable disc valve can readily be housed in a pick-up having a stem of external diameter of ¼in. An even smaller size of stem appears practicable. Such units

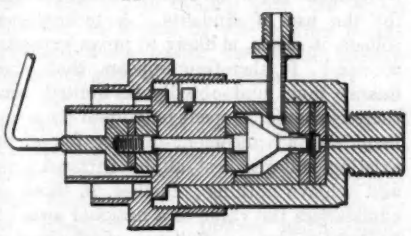

FIG. 3—STEAM CONDENSER DISC VALVE

can be accommodated in cylinder-heads in which no provision has been made or can be made for a pick-up of normal size. Even where an indicator passage is provided, an advantage is frequently gained, since such passages are often of sufficient length, particularly in high-speed engines, to produce large high-frequency pressure fluctuations by wave action. The methods previously adopted to overcome this difficulty have left the result in considerable doubt. The new pick-up may be inserted into the indicator passage after this has been enlarged if necessary. Such passages are commonly of ¼in diameter even in the smallest engines and the removal of $\frac{1}{16}$in from the surrounding wall by drilling to ¼in diameter is usually practicable. In this manner the total effective passage length can be reduced to ¼in or less. This is of importance even though, as pointed out earlier, the balanced disc valve unit cannot respond to the high frequency pressure changes which occur under some conditions in the cylinder and other parts of the engine. The elimination of the passage eliminates the spurious scatter of points due to wave action in the passage. The stem of the unit may be made as long as necessary.

In view of the difficulty of accommodating either a permanent magnet or an electromagnet of suitable size in the available space, the unit was arranged as a condenser, the capacity of which is changed by movement of the disc.

The condenser-type balanced disc valve unit design is shown in Fig. 3, and the simple input circuit which feeds the thyratron control unit is given in the report. The components of the input circuit are housed in a small fitting, which connects the disc valve unit to the cable leading to the thyratron control unit. The input circuit was fed by a 150V high-tension battery. A stabilised supply could readily be embodied in the thyratron control unit for this purpose. With this arrangement the delay periods for

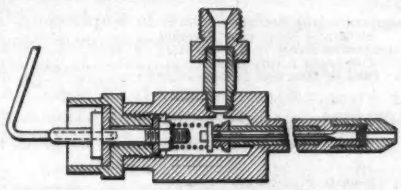

FIG. 4—SHORT CONDENSER DISC VALVE

various rates of pressure change were measured by the method described for B.I.C.E.R.A. Engine Indicating System 1, with results similar to those for the Sunbury disc valve unit. The condenser-type pick-up was found to be somewhat less shock-sensitive and thus more suitable for use in cases where there is serious vibration, since this tends to produce spurious points in the diagram.

In view of this a short and more robust form of condenser-type balanced disc-valve unit was constructed for use in cases where the stem-type unit offers no advantage. The design is shown in Fig. 4.

For reference purposes the combination of either design of condenser-type disc-valve unit, the input circuit, the control unit and the Farnboro' recording unit has been termed "B.I.C.E.R.A. Engine Indicating System 2."

System 1 has been in use in the laboratory long enough to show that it is reliable and does combine the accuracy of the Sunbury point-by-point method with the speed of the Farnboro'.

System 2, which incorporates the condenser-type disc-valve unit, has been employed successfully for several applications, but it is considered that System 2 has not been fully tried.

The condenser-type units may be used, without the input circuit shown in the report, with the Southern Instruments Indicator in place of the condenser-diaphragm-type unit normally employed with the equipment. Point-by-point readings have been taken in this manner with astem-type unit, but the system, being of secondary interest, has not been developed to spark diagrams.

A considerable saving of time can be expected by the use of the new equipment, especially for recording the low pressure, inlet, cylinder and exhaust diagrams previously obtained by the point-by-point method.

The new equipment will meet the requirements for certain types of work, but there is still much scope for further development of engine indicators.

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2 "Pressure Indicating for Internal Combustion Engines," R. Stansfield and J. G. Withers. THE ENGINEER, August 13, 1948, pages 152–155, and August 20, 1948, pages 178–179.

[A more recent article, "The Standard-Sunbury Engine Indicator 'Mark 6,'" E. S. L. Beale and R. Stansfield, appeared in THE ENGINEER, August 17, pages 215–217; August 24, pages 246–248, 1951.—Ed. The E.]

3 "An Improved Balanced Pressure Engine Indicator," C. J. Rallis. *Journal of the South African Institution of Engineers*, October, 1948, page 35, and *Mechanical World*, January, 1949, page 74.

4 American Instrument Company, Inc. (Silver Spring, Washington, D.C.), *Bulletin* 2152.

5 "A High-Speed Engine Pressure Indicator of the Balanced Diaphragm Type," H. C. Dickinson and F. B. Newell. *Report No.* 107, *N.A.C.A.*

"COPPER: ITS ORES, MINING AND EXTRACTION."—The Copper Development Association, Kendalls Hall, Radlett, Herts, has published a booklet, *Copper: Its Ores, Mining and Extraction*, which explains in simple language how commercial copper is derived from the ore by mining, ore dressing, smelting, refining and fabrication. The text is well illustrated and there is a map showing the distribution of copper ores in the principal producing countries of the world.

The Chemical Research Laboratory

THE annual report entitled "Chemistry Research, 1950," which includes the report of the Chemical Research Board and an account of the work of the Chemical Research Laboratory, D.S.I.R., during the year, has been published by H.M. Stationery Office, price 3s. 8d.

The Corrosion of Metals Group has undertaken fundamental research to correlate the results of oxidation studies on evaporated metal films under rigorous conditions with similar experiments on massive metal surfaces. The corrosion inhibitor developed at the laboratory consists of sodium benzoate with a smaller percentage of sodium nitrite in glycol antifreeze, but further investigations are necessary in cooling systems where aluminium is used in conjunction with other metals. Excellent results have been obtained with compounds prepared from nitrogenous bases and carbon dioxide as vapour phase inhibitors. Cyclohexylamine "bicarbonate" has so far proved the most effective.

The Pure Metals Committee has continued its work and the stock of metals now comprises antimony, cobalt, iridium, iron, lithium, potassium, silicon, sodium and vanadium in a satisfactory state of purity. Germanium in a very high state of purity has been prepared at the request of the Radio Research Board, tracer techniques being used to study the removal of the last traces of arsenic.

In the High Polymers and Plastics Section the ion exchange and allied properties of high polymers have been studied and work has begun on the fractionisation of linear polymers on the basis of chain-length.

Investigation of the influence of polymer studies on ion exchange equilibria and kinetics has proved that the selectivity of resins increases according to the extent of cross-linking but the rates of exchange decrease. Applications of ion-exchange resins as membranes and in the chromatographic separation of large organic ions have been examined. Studies of the covalent reactions of substituent groups in high polymers have been resumed, using polyvinyl-thiol as a model substance.

An independent Microbiology Section was set up at the beginning of the year, and it gave particular attention to fundamental studies of sulphide oxidising bacteria and their uses. They have been used to counter the nuisance caused by the activity of sulphate-reducing bacteria and, in combination with sulphate-reducers, as a means of producing sulphur.

The section also maintains the national collection of industrial bacteria, from which cultures, particularly of the assay organisms, are supplied to industry.

A specially designed building, for the Radiochemical Research Group, is now in course of erection. This group published, through the Stationery Office, a *Handbook of Chemical Methods for the Determination of Uranium in Minerals and Ores*. The methods described are based on the results of several years' work in the laboratory and include the new chromatographic techniques developed there.

Several papers have been published on the separation of metals by methods based on solvent extraction in conjunction with cellulose and other solid absorbents.

Adviser on House Building

IT was announced last week by Mr. Harold Macmillan, Minister of Housing and Local Government, that Sir Percy Mills had agreed to make his services available to assist the house-building drive, and that he would act as an honorary adviser on steps to be taken to increase the tempo of building. Sir Percy, who is sixty-one, is managing director of W. and T. Avery, Ltd., and is also chairman of the National Research Development Corporation. During the war he was Controller-General of Machine Tools from 1940 to 1944, and then became head of the production division of the Ministry of Production. In 1945 and 1946, Sir Percy was president of the Economic Sub-Commission of the British element of the Control Commission for Germany.

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RESEARCH AND TECHNOLOGICAL TRAINING

No one who pays a visit to an industrial research laboratory is likely to carry away with him much doubt about the value of research bodies to industry. That is a remark the truth of which becomes especially apparent at the Production Engineering Research Association's laboratories at Melton Mowbray, which we visited a short while ago. For though it is reasonable enough to suppose that controlled experiments will show how to improve upon "rule-of-thumb" workshop methods, it is startling to find how many simple experiments, besides others of a more complex nature, are only now, since P.E.R.A. came into being, beginning to be done! The conviction of that association that one of its jobs should be the education of those in industry to a realisation of the value of research and to an appreciation of its methods certainly seems justified! For the situation seems to reveal the truth of the contention in the Barlow and later Reports that there are not enough technologically trained men in industry. By an accident of timing we went, a week after visiting the P.E.R.A. laboratories, to the College of Aeronautics at Cranfield. We saw in action there an establishment not unlike one of those technological colleges that it has been proposed should be set up to increase the flow into industry of technologically trained men and we were interested to observe that this body was not as dissimilar from a research laboratory as we might have expected. For, like the Association's laboratory, the College runs "refresher" courses for men now in industry, keeping them up to date with the latest technical discoveries and advances and instructing them in their application; and, as at the laboratories, research is carried out at the College. But whereas at the laboratory research is undertaken with the specific object of applying the results in industry, at the College the students are encouraged to do such work in order to benefit, primarily, their own minds. It is a secondary, though desirable factor, that many of the researches so done prove to have value industrially.

As events fell out, we also happened to attend during the same period a debate before the Old Centralians upon technological education. It served to remind us that, owing to the change in the colour of the Government, the problem of organising further technological education in this country cannot be assumed to be settled by the White Paper issued by the Labour Government shortly before the election, accepting the proposals of the National Council on Education for Industry and Commerce, that a College of Technology should be set up. Miss Florence Horsbrugh will certainly wish to re-examine those proposals. As we see it, there exists amongst engineers to-day general agreement first that little is seriously wrong with our present educational methods, and secondly that a larger supply of technologically trained men is needed in industry. The universities having already doubled their output of technical graduates, as recommended by the Barlow Report, are unwilling to increase that output further; nor do they show much enthusiasm for affiliating to themselves technical colleges that might undertake the necessary expansion, for fear of upsetting the existing balance between the art, science and technical sides of their activities. Nor, rightly or wrongly, do they regard the provision of more specifically technological education as coming within their ambits. Unless, therefore, the views of the universities can be changed it is necessary to look elsewhere for bodies capable of training large numbers of technologists. Some, whose views were summarised by Lord Portal at the annual dinner of the Royal Society last Friday, wish to see wholly new bodies created, to act as "technological universities." But for our part we cannot see that bodies whose teaching was confined to technology could be regarded as "universities." Nor does new creation seem necessary for teaching engineering. The many technical colleges throughout the country already maintain high educational standards and many of them have close associations with local industry. According to the views of the National Council, were a suitable award available to be given by the College of Technology, those colleges could be encouraged to provide fundamental instruction to a standard equivalent to that of a university degree in the fundamental sciences of particular technologies. But for our part we feel that the specifically technological part of a technological education would need to be primarily a post-graduate affair. Since, however, the amount of specifically technological, as opposed to fundamental, instruction and research that universities would be prepared to undertake, even in post-graduate study, appears to be very limited, any technical college setting out to provide technological courses would need to make provision for much post-graduate work.

The College of Aeronautics at Cranfield provides an example of a post-graduate technological college. It is equipped with wind tunnels of considerable size, testing machines capable of stressing full-scale components of aircraft, air compressing plant to supply large quantities of air needed, for example, for tests on gas turbine combustion chamber rigs and jet systems, complete aero-engine test rigs and the like. If technical colleges are to be adequately equipped to provide technological instruction similar expensive apparatus, suited to the particular technologies concerned, will be required. Moreover, whereas fundamental technical instruction is preferably provided by small installations which do not become inadequate for their purposes as they grow older, advanced technological instruction, to be valuable, must be kept up to date. New and modern equipment must be continuously provided for the use of students. A technological college, it seems, is likely to prove expensive to run! It therefore appears that, since finance must undoubtedly be limited, what there is should be spent only upon the equipment and advancement of very few of the existing colleges, lest all be frittered away and achieve nothing; further, in those circumstances the value of a national award to be given by a College of Technology for the successful completion of approved courses becomes less obvious. It might prove better to let the awards be approved by the particular professional institutions concerned or to allow the selected colleges to rule their own affairs, jointly or individually, and make awards which, whatever the title given to them, would earn prestige through the high technological qualifications of those that held them. Furthermore, the points of similarity between the work of association research laboratories and the post-graduate work of such technological colleges suggests that a mutually beneficial relationship might be built up between them. For our part, believing that universities can provide a broader and sounder education than "technological colleges" could, we would prefer the former to train the numbers of technologists that industry requires, the more particularly that the standard of training is intended to be at least as high as that signified by the attainment of a university degree. We doubt, too, whether the foundation of technological faculties (should it seem necessary) and an increase in the number of technological students would so seriously unbalance university life as the universities seem to believe.

But if the universities cannot or will not undertake the training of the necessary men, then it seems to us desirable to elevate a very few of the technical colleges to do the work. For we cannot see how the technical colleges as a whole could be equipped to do it.

NEW KINDS OF ATOMIC WEAPONS

CAREFULLY guarded as is the information that is allowed to become public on atomic weapons of any sort, we were permitted by the publication of the Smyth report of 1945 to know that there is a minimum size in which any nuclear explosive can be used and a maximum size in which it can be safely stored as a unit. The atom bombs used in the late war seem to have been of just about the right size, and they proved, as was expected, about a thousand times as powerful as any previously known. A question which now arises, is whether this information still stands correct, or whether later knowledge shows it to be out of date? We feel impelled to raise this question in view of a speech made recently by Mr. Gordon Dean, the chairman of the U.S. Atomic Energy Commission, who claimed that owing to new advances in technique the time had arrived when not only have the quantities of atomic weapons available grown very rapidly, but they are now of "types so varied that we may utilise them in many different ways not heretofore possible," and that "we can with complete justification" treat the tactical atom-weapon in just the same manner as others. As this important announcement of Mr. Dean's came almost at the same moment as one from the White House dealing with the recent explosion in Russia of yet another locally produced atom bomb, the public interest was keenly aroused on the whole subject.

So far as Mr. Dean's pronouncement is concerned, two important questions arise: Is it really factual? And, if it is, what are the likely consequences? All atom bombs based on the fission of uranium explode by the "chain-reaction" process which results when the birth-rate of neutrons exceeds the sum of the death and migration rates by even a tiny fraction. All that is wanted for such a reaction is that there shall be more than one neutron produced by fission for every neutron "used up"; not every neutron generated can be counted on to split a further uranium nucleus, since it may itself become lodged in some other nucleus or may leak away from the surface of the mass if its mean free-path is comparable with the distance to be traversed before that boundary is reached. Hence the bare birth-rate must needs be appreciably higher than the death-rate if there is to be an effective reproduction factor. Prior calculation had predicted the probable minimum mass of fissile material that could be exploded in this way and experiment confirmed the prediction: what that minimum is has never been explicitly stated, but it was, we think, Professor Oliphant, of Canberra University, who picturesquely put it as being "about the size of a pomegranate"! With that lack of precision in our knowledge we have had to be content. But if Mr. Dean's words have their natural meaning he is telling us of something quite newly discovered—and not only new, but very important. If, for example, ordinary sizes of artillery shell can be made to carry atomic explosives of a thousand times the potency of the familiar T.N.T. filling of such shells, it may be that the power of defence against aggressive action will be increased in a remarkable and most welcome degree. Mr. Churchill has said more than once that it was to the large U.S. stockpile of atom bombs that we have owed the recent years of comparative peace in Europe. Tactical atomic weapons in the hands of the defence might prove an even surer deterrent to aggression. When writing on these matters a few months ago we quoted some figures given, without comment, in the pages of the Chicago *Bulletin of Atomic Scientists*, which suggested that the Russian stockpile of atom bombs might reach 300 or so by the year 1955, compared with a U.S.A. stock already perhaps several times as great. What progress may have been made, in any country, with preliminary work on the alternative of the hydrogen bomb referred to in President Truman's announcement of January, 1950, is not revealed, but if, with its potential thousandfold further increase of power, that bomb should, as seems likely, require in each case a uranium bomb as its detonator, the importance of a substantial stockpile of the latter needs no emphasis. At the same time, if the technical advances made lately by the U.S.A. and its Allies in the design of atomic weapons are as great as Mr. Dean seems to suggest, atomic warfare will no longer be solely a means of retaliation for an act of aggression already committed, but will be able to stop the aggressive action in its very stride. We notice that so watchful a journal as the *Manchester Guardian*, in a recent leading article, went so far as to offer the comment that the new weapons might have a profound effect in Korea "if and when they are introduced."

There has always been a strong reaction—and in many ways a healthy one in a world not unfamiliar with the idea that there are risks enough already—against the coming of any novel kinds of weapon. We learnt at school of the dismay created by the invention of the early cross-bow; of the reaction of the great Chevalier Bayard, so humane to all ordinary captives, but making an example of those found to be in the possession of firearms of any kind. We have seen a similar reaction (with some admixture of political bias) to the use by the U.S. of its atom bombs over Japan, although the damage done at either Hiroshima or Nagasaki was less than that in a previous raid on Tokyo with normal incendiary bombs. But the development of these new tactical atomic weapons, it has been suggested, may prove sheer gain, since on Mr. Dean's showing they may provide the one effective answer to aggressive action on the part of any power-seeking dictator wherever or whenever he may appear. In fact we feel less optimistic upon that point than certain other commentators, though we hope that assessment of the situation is the true one. We hope, too, that the British Services will be no less well equipped than those of its great ally on the other side of the Atlantic with these new tactical atomic weapons without which no army (and possibly no Navy or Air Force) will, in the future, be regarded as fully up to date.

Literature

Transatlantic Paddle Steamers. By H. PHILIP SPRATT. Glasgow: Brown, Son and Ferguson, Ltd., 52–58, Darnley Street, Price 7s. 6d.

THE paddle steamer has always appealed to the engineer in a special way in that it seems to possess a vitality and personality not found in vessels dependent on later forms of propulsion. A measure of regret was experienced when the twin-screw oil-engined ship invaded the Solent and narrow seas in recent years, and it was a sad day for many of us when the last cross-Channel paddler disappeared from the Straits of Dover in 1923. We have to go right back to 1875 for the year when the last British paddle steamer, the Cunard Steamship Company's "Scotia," built in 1861, crossed the Atlantic, after which, as Mr. Spratt says, perhaps a trifle unkindly, "their clumsy, honest old paddles were superseded by the more efficient screw propeller."

There is a certain fascination attaching to some of these early steamers, and the author of "Transatlantic Paddle Steamers" has rendered a real service in giving us a comprehensive record of the whole period since the celebrated American vessel, "Savannah," built in 1818, crossed the Atlantic. Although equipped with paddle wheels the faith of the designer cannot have been very great, for it was arranged that the paddle wheels could be folded up and taken on deck, and, indeed, for the crossing of the Atlantic sails were largely used. Mr. Spratt assures us that it was a British steamer that first made the westward passage, the "Rising Star."

This book is divided into three sections, the first dealing with some of those interesting pioneers which braved the Atlantic in a somewhat spasmodic fashion, and when we consider their dimensions we wonder at the venturesome nature of those who trusted themselves to these fragile craft, which had none of those aids to navigation which are regarded as so essential nowadays; indeed, we should be aghast if a ship's log recorded "No cole to git up steam"! The second chapter is entitled "Sustained Steam Power," when, instead of vessels being really sailing ships with auxiliary engines, it became a matter of steamers with auxiliary sail, as in the period 1833 to 1840. The third chapter deals with the "Atlantic Paddle Ferry," between the years 1840 and 1875, the famous "Britannia" being built in 1840 and inaugurating the regular service which has been maintained ever since by the Cunard Steamship Company. This vessel was better fitted out than her predecessors, and carried 115 passengers, 225 tons of cargo, and maintained a speed of 10 knots on the crossing which entitled her to the "Blue Riband of the Atlantic." It seems rather unfair to take the dreary description of this notable vessel given by Charles Dickens in his "American Notes" as fair comment, for it would appear that he was by no means a good sailor. Size and speed of vessels gradually increased, and in 1848 "America" attained a mean speed of 11·25 knots, with a boiler pressure of 18 lb per square inch. The last paddler "Scotia" reached a speed of 16·5 knots. The price that had to be paid for the development of transatlantic travel is shown by the story of fine ships lost at sea. No work of this nature would be complete without a description of the "Great Eastern," and we are given an excellent account of her. Built in 1858, she was not exceeded in dimensions until 1899. She was propelled by a combination of paddle wheels and screw, and though a

triumph of the skill of the naval architect of that day, she proved to be a financial failure, and her best work was as a trans-atlantic cable ship between 1865 and 1873. It seems strange to read of steamers with boilers fed with sea water, which necessitated their being cleared of salt every fourth day, and it was not until the invention of the surface condenser in 1834 that boilers could be kept in continuous operation.

Altogether, we have a most interesting book before us, describing, as it does in considerable detail, thirty-two famous vessels. This survey must have involved considerable spade work, and it should be a valuable addition to the number of books describing the history of the steamship, for it covers those early years which have not hitherto been dealt with so comprehensively, while the style of presentation makes reading not only informative, but easy. At the end there are useful tables giving the principal dimensions of all the vessels described, and particulars as to their machinery and service. The book is illustrated with nine full-page plates.

SHORT NOTICES

The Behavior of Engineering Metals. By H. W. Gillett. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd. 1951. Price 6.50 dollars.

This, the final, contribution by the late Dr. Gillett to technical literature, is not addressed primarily to the metallurgist, but to any technologist who may participate in the selection of metals and alloys for engineering uses. It was written in order to further the co-operation of designers, metallurgists, production engineers, purchasing agents and sales engineers, by helping them to understand each other's language. The first six chapters introduce the basic concepts of metallurgy. The next nine deal with the behaviour of each of the principal commercial metals and alloys. The remainder of the book is devoted to special considerations that may influence the selection of metals and alloys, such as machinability, resistance to corrosion, high temperatures or wear, and finally cost and availability. The book will be of more value to American than to British technologists, mainly because all the specifications quoted are American and, although there are some references to work done outside America, almost all the data given are based on the results of American tests and American experience. This, however, does not detract from its usefulness as an introduction to the relevant facts about metals and alloys as engineering materials. These are set out in an interesting way with many little side lines of information. Moreover, there is much in the book about such subjects as the limitations of conventional tests, notch sensitivity and quality control, to which metallurgical specialists would be well advised to devote more attention.

BOOKS RECEIVED

Power Transmission Directory, 1950–52. London: Trade and Technical Press, Ltd., 65–66, Chancery Lane, W.C.2. Price 5s.

Ship and Boat Builder Year Book, 1951. London: John Trundell, Ltd., Temple Chambers, Temple Avenue, E.C.4 Price 25s.

Water Engineers' Handbook, 1951. London: The Colliery Guardian Company, Ltd., 30–31, Furnival Street, E.C.4. Price 15s.

Construction with Moving Forms. By L. E. Hunter. London: Concrete Publications, Ltd., 14, Dartmouth Street, S.W.1. Price 7s. 6d.

The Human Use of Human Beings. By Norbert Wiener. London: Eyre and Spottiswoode, Ltd., 15, Bedford Street, Strand, W.C.2. Price 18s.

The Mercantile Year Book and Directory of Exporters, 1951. London: Lindley-Jones and Brother, Ltd., 52, Bishopsgate, E.C.2. Price 26s.

Technologie des Holzes und der Holzwerkstoffe. By Dr.-Ing. Franz Kollmann. Germany: Springer-Verlag, Reichpietschufer 20, West Berlin. Price Dmk. 136.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

STRUCTURAL LIGHT ALLOY RIVETING

SIR,—My attention has been drawn to a letter by Dr. Williams in THE ENGINEER of October 26, 1951, commenting on an article of mine published in THE ENGINEER of August 24, 1951. I seem to have caused Dr. Williams some annoyance, probably because I have used the word "structures" in the particular sphere as applied to the civil engineering type of structure. I apologise if I have not made this clear and have misled him into thinking I was in any way referring to aircraft structures.

Dr. Williams's reference to my opening remarks on the soft riveting alloys, however, is in any case rather misleading. He implies that I stated that the soft riveting alloys are inadequate for structural work. This is, of course, quite incorrect. What I said was that the small rivet, as developed by the aircraft industry up to approximately ⅜in diameter in the soft alloys, was inadequate and I then tried to show that greater economies can be obtained by using the high tensile alloys in larger diameters, as required for this type of work, than by using even larger diameters in these same soft alloys.

I have not been able to trace the alloy R.37, referred to by Dr. Williams. If by any chance he means L.37 or H.14, then this is the well-known riveting alloy that is used immediately after solution heat treatment or, alternatively, is stored in a refrigerator until required. Rivets in this alloy are therefore closed in the soft condition and natural age hardening occurs after riveting. Unfortunately, this is a practice that is not suited for normal structural work and I therefore did not refer to it in my article.

With regard to Dr. Williams's remarks on stress distribution among rivets I am sure that his own paper must be of great value to the aircraft industry, but I have found nothing in it which can affect the conclusions I have given for the type of structural work I have mentioned. The structural engineer is well aware that there is unequal distribution in a row of rivets and also that some of the more heavily loaded rivets must reach yield stresses and higher. If this were not so there would be no plastic deformation and redistribution of stress would not take place. The same argument applies to the relief of concentrated stresses at discontinuities and to the relief of locked up rolling and welding stresses. In fact, if, as I understand Dr. Williams suggests, design is aimed at keeping such stresses below the yield point, there would be no value in using material with any ductility at all as the ability of metals to deform without fracturing would not be called into play.

I did not mention these facts in my article because they are common knowledge; the point which I discussed was whether the assumed mean working stresses should be based on a factor of safety applied to the ultimate value of rivet and plate or on a lesser factor of safety applied to the yield and proof stresses. If such working stresses are based on ultimate strengths then in the worst cases some allowance must be made for maldistribution, as has been shown by the work of Professor S. C. Redshaw, summarised and presented at the Aluminium Development Association Symposium on Welding and Riveting Larger Aluminium Structures on November 13, 1951. If, on the other hand, these working stresses are based on the yield and proof stress then no allowance need be made even with the high strength alloys.

Dr. Williams has hinted darkly at the effect on the life of a joint of such uneven distribution in rivets and from his paper I conclude he is referring to fatigue. Here, of course, is one of the great differences between aircraft and civil engineering structures. It is indeed very doubtful whether fatigue conditions have any effect at all on the latter type of structures and many structural engineers hold this view. I can at least assure Dr. Williams that he need have no fear in crossing any of the many thousands of riveted and bolted bridges that have been standing for fifty years or more, despite uneven distribution of load between the bolts and rivets.

J. G. WHITMAN

Military Engineering Experimental Establishment, Christchurch, Hants, November 23rd.

NUMBER 5000

SIR,—May I, a contributor to your columns for upwards of thirty years, offer my congratulations on the publication of the 5000th issue of THE ENGINEER. I feel it an honour to have an article of mine in this notable copy of your paper.

In reading your interesting survey of so many years, I would like to make some further reference to THE ENGINEER during the year 1894. You mention in particular the trials of a cruiser built by Sir W. G. Armstrong Mitchell and Co. for the Chilian Government, published in that year. I recall that number of THE ENGINEER quite clearly for the reason that you then gave your readers, of which I was one, a fine drawing with an equally good description of a locomotive of great historic interest. I refer to the first six-coupled bogie engine for a British railway, the celebrated Jones "Goods" for the Highland line. While yet another article in the same issue was an interesting description of the Atlas Works, Glasgow, Sharp, Stewart and Co., the firm who built the Jones six-coupled engines. Though then in my middle "teens," I can remember as if it were yesterday investing my Saturday sixpence in this noteworthy number of a paper I have read, I may say, constantly one year after another up to No. 5000.

E. C. POULTNEY

London, N.W.3, November 27th.

COMPOUND LOCOMOTIVES

SIR,—Referring to Mr. Poultney's article on compound locomotives, may I ask whether he considers that the three-cylinder system, which we in this country associate with the names of Smith, Wilson Worsdell, and Johnson was an original British invention?

On page 392 of *Engineering* for November 23, 1866, there is an article dealing with a French three-cylinder engine, which suggests that the system, or something very like it, was in use in France more than thirty years before the rebuilding of our North-Eastern engine 1619; and it would be very interesting to know whether Gateshead and Derby had French experience in mind.

The earliest French experiment in compounding, which I ever saw, was the Webb three-cylinder engine, which Sharp, Stewart built for the Ouest Company in 1884; and I have never come across any information with regard to the engine of 1866, which seems to have been forgotten by railway historians.

W. B. THOMPSON

United University Club, S.W.1, November 26th.

1000kW ALLEN GAS TURBINE

SIR,—The description of the Allen gas turbine which has appeared in recent issues of THE ENGINEER has provided turbine engineers with a fuller description than usual of mechanical detail, and I have subjected it to considerable scrutiny. On page 652 there is a description, with a drawing, of the segmental shroud ring.

To the uninitiated it might appear that this means of controlling the blade tip clearance was originated by W. H. Allen, Sons and Co., Ltd. The facts are otherwise; it was devised by the writer in January, 1945, and is covered by Patent No. 597165, which was taken out jointly with Power Jets (R. and D.). It is true that the cooling air flow arrangement in the Allen design is different from that shown in Patent No. 597165, but the keypoint is that the support ring is cool, and the hot shroud ring expands circumferentially. Incidentally, I do not think "spiral helix" is a good description of the twisted strips. Surely the nearest thing to a spiral helix is a conical spring. Another feature which originated at Power Jets is the resilient bolt which holds the compressor rotor together. This appears in Patent No. 610314. There is also other evidence of Power Jets influence, which is not altogether surprising, having in mind the fact that Mr. Pope, its designer, was once a member of the Power Jets design team. I have no desire to detract from the good work done by Mr. Pope, Mr. F. S. Smith and others, but as the assistance given by the Bristol Aeroplane Company is acknowledged, I think it would also be proper to give Power Jets its due as well.

R. C. McLeod

Leicester, November 27th.

[The contributions of Power Jets, Ltd., to gas turbine design have been so considerable that there is certainly a tendency to "take them as read." Our correspondent's letter does good service in drawing attention to the influence of that firm's work upon the design of the particular turbine concerned.—Ed., The E.]

Gloster "GA5" Twin Jet Delta Fighter

Certain details of the Gloster "GA5" Delta aircraft, which first flew last week, have now been released. This machine is the first aircraft with a triangular wing planform to be specifically designated as a fighter aircraft suited for multi-purpose operations and fitted with electronic intercepter aids. It has two Armstrong Siddeley "Sapphire" jet turbines, each developing over 7000 lb static thrust at sea level, mounted in housings which are integral with the fuselage and wing roots, the circular air inlets being placed forward of the roots.

The adoption of the Delta for military purposes marks a most significant advance in the development of high-speed aircraft. The speed, range, armament and electronic aids associated with this machine are not disclosed. It is stated in favour of this design that its low aspect ratio confers superior stability and control characteristics at sonic speeds, and that apart from other quite fundamental aerodynamic requirements which it fulfils, the design permits of the engines, undercarriage, fuel and equipment to be contained inside one smooth envelope, which is inherently a rigid and economical structure.

The Hawker Siddeley Group, of which the Gloster Aircraft Company is a member, has been concentrating for some time past on Delta development. Its sister company, A. V. Roe and Co., Ltd., has done much successful basic research on Deltas as has been evinced by the recent demonstrations of the experimental Avro "707" machines.

We were able at the time of the recent S.B.A.C. display to include in our report some notes on Delta aircraft prepared by the A. V. Roe and Co., Ltd.

In the development of the "G.A.5" machine there has naturally been an exchange of research information between the two companies, which has been made complete by employing "Sapphire" engines made also by a company within the Hawker Siddeley Group.

Agricultural Machinery Exhibition at Earls Court

No. II—(*Continued from page 700, November 30th*)

The Smithfield Club Show and Agricultural Machinery Exhibition was opened at Earls Court, London, last Monday, and will end this Friday, evening. Throughout the week the exhibition has attracted large numbers of visitors from home and overseas. The cattle exhibits have this year been the centre of particular interest, as butchers have once more been permitted to bid at auction for the live cattle on show. The livestock entries are, regrettably, fewer in number owing to the prevalence of foot-and-mouth disease in several parts of the country and consequent prohibition on the movement of cattle.

There is, however, no diminution in the amount and variety of machinery and equipment displayed. At this year's "Smithfield"—the third in the post-war series—the tractors, farm implements and equipment for the meat and kindred trades which are exhibited are an impressive reminder to engineers, farmers and lay visitors alike of the continuing progress and high technical standard of agricultural mechanisation. In what follows we continue our description of some of the machinery exhibits.

During the present year two new tractors have been introduced by David Brown Tractors, Ltd., Meltham, Huddersfield. Both of them are included in this company's display of tractors and implements at Earls Court. The first is the "Cropmaster Diesel 50," which was illustrated and described in the article on the Royal Show published in our issue of July 6th. On that occasion we made brief reference to the other new tractor—the "Trackmaster Diesel 50"—which is illustrated in Fig. 6. This tractor is fitted with a six-cylinder diesel engine capable of developing 50 b.h.p. at a maximum governed speed of 1800 r.p.m., and giving a belt horsepower of 42·5. Speed is maintained by a pneumatic governor, and a decompressor is provided to assist starting in cold weather. The bore is 3⅜in and the stroke 4in and there is direct fuel injection through equi-spaced sprays into a toroidal shaped combustion chamber. Transmission is through a Borg and Beck single dry plate clutch to a twin-range three-speed gearbox, which gives six forward and two reverse speeds. The forward speeds range from 1·06 m.p.h. in first low to 6·43 m.p.h. in third high, with the engine running at 1800 r.p.m. The steering is on the "Duotrack" system, incorporating a geared epicyclic differential and contracting band brakes, a system which gives a predetermined turning radius, and power is delivered to both tracks all the time. The "Trackmaster 50" is being made available with a choice of three track widths, 48in, 56in, or 64in, the width of the standard track plates being 14in. The equipment includes a four-speed power take-off and, if desired, a rear-mounted belt pulley which is driven directly from the power take-off shaft.

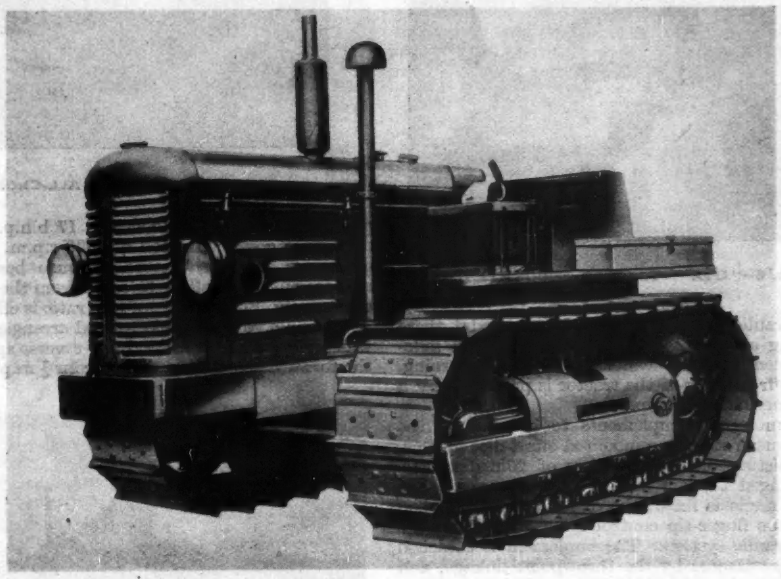


Fig. 6—"Trackmaster Diesel 50" Tractor—David Brown

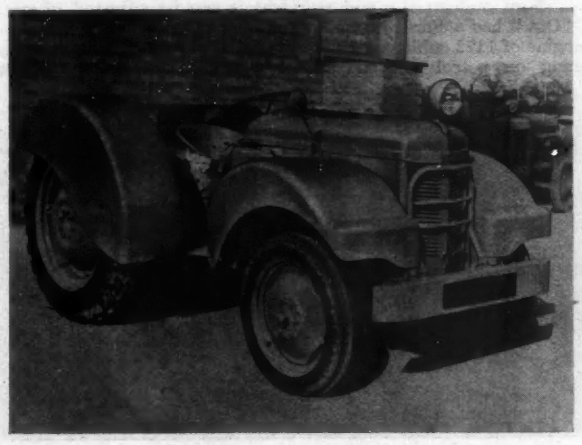


Fig. 7—Industrial Tractor—Ferguson

The tractor shown in our illustration, Fig. 7, is the industrial version of the "Ferguson."

It is exhibited, in company with the firm's agricultural tractors, by Harry Ferguson, Ltd. This industrial tractor is very similar to the various Ferguson agricultural tractors. It can be supplied either with a four-cylinder petrol or vaporising oil engine developing about 28 belt horsepower. The tractor, which is equipped with a hydraulic lift and power take-off, is built to conform to all legal requirements for public road work, with the mud-guards easily detachable should it be desired to convert it to agricultural and other purposes. There is provision for four forward speeds between 3¾ m.p.h. and 13¼ m.p.h. at an engine speed of 2000 r.p.m., and one reverse speed of 3¾ m.p.h. The rear wheel brakes are operated

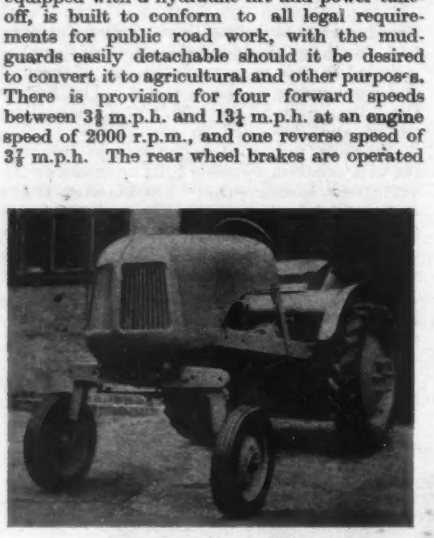


FIG. 8—"OTA" TRACTOR—SLOUGH ESTATES

hydraulically by a combined brake pedal, there being a separate mechanically operated independent braking system to facilitate turning. The front end of the tractor is protected by a spring-loaded bumper.

Among the implements to be seen on the Ferguson stand is a mounted offset disc harrow, consisting of fourteen discs of 20in diameter, arranged tandem fashion in two gangs. The disc angle is fixed, the depth being controlled by the finger-tip control lever of the tractor's hydraulic system. The implement is attached to the tractor by the three-point linkage, and offset is obtained by slackening the clamps and sliding either or both gangs of discs to the right or left. The total offset can be up to 6ft from the centre of the tractor and the narrowest working width is 5ft 3in, the maximum being 7ft 3in. The relationship of the front and rear discs is governed by a hand lever, and adjustable scrapers are provided so that the discs can be kept clean whether clogging tends to occur on the periphery or near the centre.

In addition to the heavy and medium tractors to be seen at Earls Court, there are exhibited many light tractors suitable for a variety of farm or market garden tasks. An example is illustrated in Fig. 8, which shows the "Ota" Monarch four-wheeled tractor, made by Oak Tree Appliances, Ltd., and marketed by Slough Estates (London), Ltd., 16, Berkeley Street, London, W.1. About two years ago this firm produced a three-wheeled tractor powered by a four-cylinder 10 h.p. Ford industrial engine. The four-wheeled "Ota" has a Ford four-cylinder water-cooled engine of 1172 cubic centimetres capacity, running on petrol or

FIG. 10—"ALL-CROP" HARVESTER—ALLIS CHALMERS

power kerosene, which develops 17 b.h.p. at a maximum governed speed of 2000 r.p.m. The gears run in plain phosphor-bronze bearings and are automatically lubricated from the back axle supply. The change of gear ratio is effected by a simple yoke and selector rod arrangement, which gives six forward and two reverse speeds, the forward speed range being from ¾ m.p.h. to

FIG. 11—DISC HARROW—RANSOMES

15 m.p.h. Burman steering gear gives good manœuvrability and permits a turning radius of just under 8ft. The wheel base of the tractor is 5ft 2in and the tracks of both the front and rear wheels can be adjusted in small intervals from 3ft 6in to 5ft. The ground clearance is 16in. Without wheel weights or ballast, the tractor weighs approximately 13 cwt and is able to exert a drawbar pull of 1950 lb. The special equipment includes a hydraulic lift and three-point linkage, a power take-off with a rated speed of 550 r.p.m., and a four-speed 10in diameter belt pulley running at a belt speed of 3000ft a minute when in top gear.

The implements exhibited by Ransomes, Sims and Jefferies, Ltd., Orwell Works, Ipswich, include a representative selection of the mounted and trailing ploughs made by that firm. It is interesting to recall that the first Ransome plough was built as long ago as 1789 by Robert Ransome, who, in the early part of last century, invented the chilled share. There is certainly a striking contrast between the ploughs of that date and those of to-day, many of which are designed for use with tractors sufficiently powerful to draw five or six furrows.

An implement recently introduced by the firm is the "Hussar" five-furrow disc plough, a photograph of which is reproduced in Fig. 9. In its design, particular attention has been given to weight distribution. The plough is built around a beam of square section high-carbon steel, the front and rear castings and the disc standards being secured by bolts and clamps. The manganese steel discs rotate on tapered roller bearings, which are completely sealed against dust and grit, and the disc standards provide for three alternative cutting angles to give maximum ground penetration. Normally, the discs are 24in in diameter, though 26in diameter discs can be fitted. The front and rear furrow wheels consist of steel rims, to which cast tyres are bolted. The sharpness of the rims and the angle at which the wheels are set give a maximum grip of the soil under the hardest conditions, while the width of the tyres prevents sinking when the ground is soft. The clutch mechanism of the power lift runs in a sealed oil bath, and the plough can be raised or lowered in half a revolution of the land wheel, which is deeply webbed to provide adequate drive. The drawbar can be adjusted vertically and horizontally and the draught is taken straight through to the rear of the plough. A hand screw, operating on the land wheel, controls the depth of work, which can be varied up to 9in with 24in discs or 10in with 26in discs. Levelling is effected by a long lever operating on the front furrow wheel and a hand screw by which the rear furrow wheel can be adjusted.

Another tillage implement shown by Ransomes, Sims and Jefferies, Ltd., is the mounted disc harrow, illustrated in Fig. 11. It is a well-balanced tool for pulverising the clods left by the plough, and is an implement which can be offset either to the right or left of the tractor to allow work in such places as orchards where young trees may be growing. The harrow has been designed for tractors fitted with a hydraulic lift and standard three-point linkage, and its

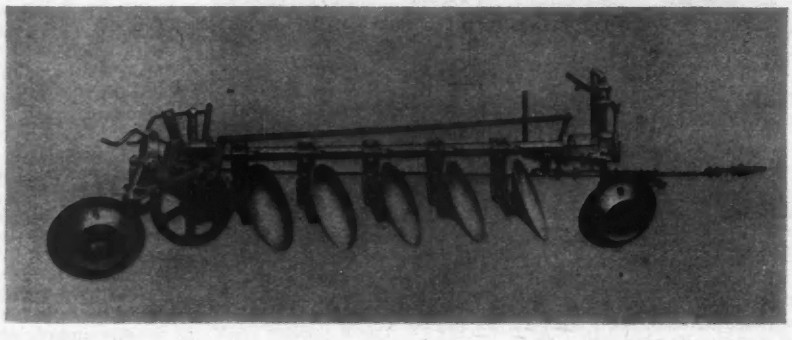


FIG. 9—"HUSSAR" DISC PLOUGH—RANSOMES

general construction and short coupling permit a small turning radius—a particularly important point when cultivating small areas. The weight of this implement is 8 cwt. It has eighteen carbon steel discs, 20in in diameter, which are arranged in two gangs of nine and are spaced at intervals of 9in. These discs are carried on a strong frame built of steel angle bars. A disc guide, which is adjustable for depth, is fitted in the centre of the harrow to counteract side draught on the tractor. The tripod can be moved along the front frame bar when the harrow is wanted in offset position, and two diagonal stays take the draught straight through to the rear of the harrow. When the harrow is in the offset position these stays are coupled together. In work, the front gang of discs throws the earth to the right and the rear gang to the left, thereby cutting out ridges and leaving the ground level. The working angle of the gangs can be adjusted by a hand screw.

An example of the harvesting machinery displayed at Earls Court is the "All-Crop" harvester, a view of which is reproduced in Fig. 10. It is built by Allis-Chalmers Manufacturing Company, Totton, Southampton, and has been designed to deal with all kinds of grain, with beans, and also with seeds such as clover. Any general-purpose farm tractor equipped with power take-off is suitable for operating the harvester, the body of which is built from rectangular sheet steel. A four-bat reel directs the crop on to the hinged header of the machine, which takes a 5ft knife, and passes it to the platform, the upper and lower canvases of which carry it to the threshing cylinder. This cylinder is 5ft wide and 15in in diameter and its speed can be varied between 450 r.p.m. and 1600 r.p.m. It carries two interchangeable concaves and one adjustable rubber-faced shelling plate. A conveying riddle delivers the threshed grain and chaff to the front end of the cleaning shoe, which incorporates a four-bladed 18in diameter underblast fan and finishing and cleaning sieves. The clean grain is delivered to a grain pan by gravity through a screen in the tailings elevator, but there is a "tailings recleaner," which takes back any unthreshed heads to the front and centre of the cylinder for rethreshing. Curved mould board straw deflectors take the straw from the threshing cylinder to the front end of a vibrating rack, which is 10ft long and 2ft 8in wide, and which has a separating area of 26 square feet. The drive from the tractor power take-off to the various parts of the harvester is taken by five vee belts and four chain drives, safety clutches having been provided at all particularly vulnerable points.

(To be continued)

The Union Castle Line Steamship "Rhodesia Castle"

ON October 18th, the S.S. "Rhodesia Castle" sailed from London on her maiden voyage in the Union-Castle Line's round-Africa service. She is the second one-class ship to be built for the company, the first being the "Bloemfontein Castle," which was completed last year and was described in THE ENGINEER on April 14, 1950. Before sailing we were able to visit the vessel at the invitation of the Union Castle Company and there is no doubt that a high standard of comfort has been provided for the passengers.

Harland and Wolff, Ltd., built the ship at Belfast under the survey of the Ministry of Transport and of Lloyd's, and the photograph reproduced below shows the raked stem and cruiser stern, which, together with a low streamlined funnel, two masts and well-rounded bridge front, presents a pleasing and dignified profile. There are four complete steel decks and an orlop deck forward and aft of the machinery spaces. Nine watertight bulkheads, extending to the upper deck and fitted as required with electrically operated watertight doors, divide the ship in ten watertight compartments, and there are five holds, two forward and three aft of the engine and boiler-rooms, several of which are insulated for the carriage of citrus fruits.

The following are the main particulars:—

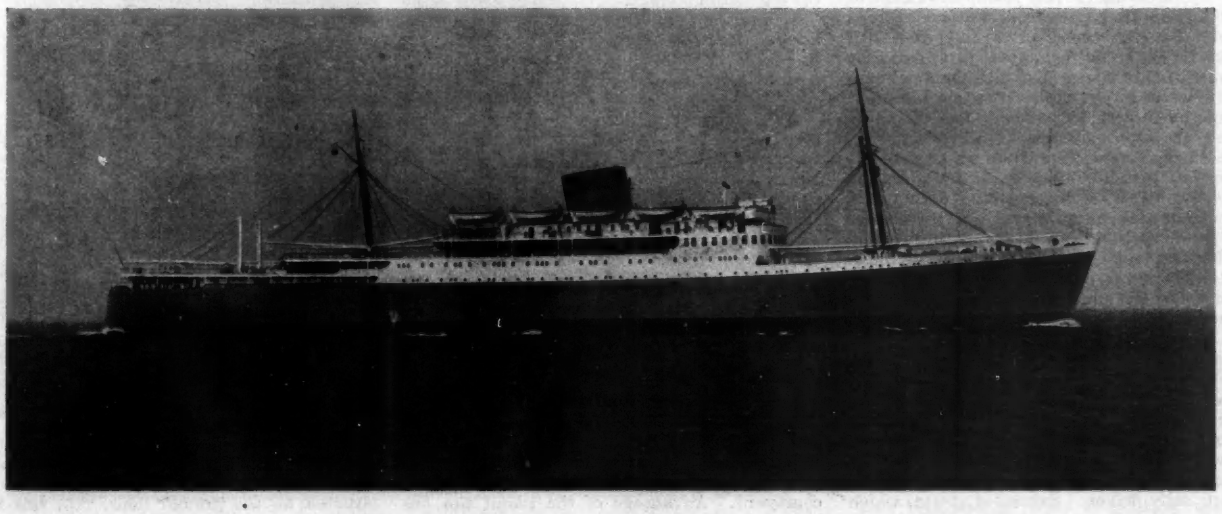
Length overall	576ft
Length between perpendiculars	540ft
Breadth moulded	74ft
Depth moulded	35ft 6in
Gross tonnage	17,041
Service speed	17·5 knots
Normal power	12,000 s.h.p.

The total number of passengers carried is 530 and they are accommodated in one, two, three and four-berth cabins, each of which is well furnished and there are a number of private bath rooms. As already mentioned, all passengers are of one class and so all have full use of the public rooms and recreation facilities. Spacious decks are a feature of the ship and the public rooms on the promenade deck are all well proportioned and furnished. The lounge extends the full width of the promenade deckhouse and has, as its principal decoration two oil paintings presented by Southern Rhodesia. Aft of the lounge vestibule, on the port side of the ship, is a long gallery library which is comfortably furnished with settees and armchairs, and leads to the after vestibule. This, in turn, opens on to a large smoke room (seen in our illustration), which extends the full width of the deckhouse. The promenade deck has been extended further aft than in previous ships, the additional deck area providing space for deck tennis, without interfering with those passengers who wish to promenade It forms also, a balcony from which to view the lido on the deck below.

Recreational activities are well catered for and the boat deck has been specially laid out for sport, while at the forward end there is a small covered verandah for the comfort of those passengers who prefer to watch the games in progress. On "C" deck aft there is a large open-air swimming pool and additional facilities for the playing of deck games; there is also an extensive covered deck space where refreshments will be served during the day and dances held in the evenings. Forward of this space, which is known as the verandah and is protected from inclement weather by hinged and glazed screens, is a comfortable oak panelled room, called the club room, which is available to passengers who prefer not to make use of the more formal smoke room or lounge on the promenade deck. On the other side of the ship is a space specially reserved for the children. Here they have a paddling pool and sand pit and a portion of deck reserved as a playing space in addition to a playroom which is well equipped with toys.

The main passenger entrance is on "B" deck, and access to the dining saloon on "A" deck is by a main staircase and an electric lift. The dining saloon, which seats 280 passengers at tables for two, four, six and eight, extends for the full width of the ship. It is air conditioned and is served from an electrically equipped galley and other departments which are placed immediately aft.

Fire protection arrangements include a Lux Rich detecting and extinguishing system covering the cargo spaces, and a Grinell sprinkler system is fitted throughout the passenger and crew accommodation. Navigation aids include all the latest equipment and the streamlined rudder is operated by electric-hydraulic steering gear. The electrically operated watertight doors are arranged for local control in addition to the main control from the navigating bridge, and the life-saving arrangements include nine lifeboats fitted with hand-propelling gear and one motor lifeboat, all being carried under Taylor gravity davits. Deck machinery and cargo-handling gear include four electric warping capstans, two forward and two aft, and electric winches for working the complement



UNION CASTLE STEAMSHIP "RHODESIA CASTLE"

THE SMOKING ROOM

of tubular steel derricks, one of which lifts 30 tons, six are for 10-ton lifts, and four can handle loads of 5 tons.

MACHINERY

The ship is propelled by two sets of Parsons triple-expansion, double-reduction geared turbines, constructed by the shipbuilders, which give the vessel a service speed of 17·5 knots. Steam is supplied at 450 lb per square inch and 750 deg. Fah. to the turbines, which develop a normal ahead power of 12,000 s.h.p. at about 100 r.p.m. of the propeller.

The ahead turbines are of the all-reaction design, while the h.p. and l.p. astern turbines, which are incorporated in the i.p. and l.p. casings, respectively, have all impulse blading. The reaction blading is of stainless iron segmentally fitted and end tightened, while the astern impulse blading is of stainless steel. All the blading is mounted on solid forged drums, and the h.p. ahead and astern, i.p. ahead and l.p. astern casings are steel castings, while the l.p. ahead casing is of cast iron. The double reduction gearing is of articulated design and each turbine is connected to the gearing by a claw coupling, the whole being housed in a fabricated steel gear case.

Steam is supplied at 450 lb per square inch and a total temperature of 750 deg. Fah. by three one-pass Babcock and Wilcox oil-fired, water-tube boilers fitted with the boilermaker's fuel-burning equipment. One motor-driven Howden-Ljungstrom regenerative air heater is incorporated in each boiler and the steam plant operates under the Howden system of forced and induced draught. There is one forced draught fan for each boiler and each can deliver 13,600 cubic feet of air per minute at a temperature of 80 deg. Fah. against a pressure of 2·7in water gauge, while the induced draught fans each deal with 19,200 cubic feet of air per minute at a temperature of 270 deg. Fah. against a pressure drop of 2·6in water gauge.

The l.p. turbines exhaust into underslung condensers of Weir regenerative design and the condensate passes through a three-stage system of regenerative feed heating before entering the boilers. Four vertical centrifugal circulating pumps supply the cooling water to the condensers, and included in the auxiliary system are a non-vacuum condenser, hot well drain tanks and the feed pumps, one of which is turbine-driven while the other is an electrically driven seven-throw displacement pump. Make-up feed for the boilers and fresh water for the ship's use are provided by two evaporators in conjunction with a distiller. With the exception of the standby main turbo-feed pump and the auxiliary feed pumps, the auxiliary machinery is electrically driven. Saturated steam, which is required for the ship's hotel services, tank heating and other purposes, is supplied by two Cochran oil-fired auxiliary boilers.

The electrical power required for engine-room auxiliaries, heating, lighting, cooking, refrigeration and air-conditioning plant, galley and pantry equipment, steering gear and deck machinery, which totals 3550kW, is provided by two turbo-generators and three diesel generators, all of which are located in the engine-room aft of the main turbines. Each turbo-generator is a self-contained unit complete with surface condensing plant, air injector and attendant pumps, and has a capacity of 750kW, 220V, d.c. The diesel generators were supplied by the engine builders, each being rated at 450kW, 220V d.c., and the engines are of the two-stroke, eccentric opposed piston design. All the diesel generators are complete in themselves, being equipped with separate pumps, coolers, filters, silencers, air compressors and starting air reservoirs. In addition to the main generating plant there is an emergency 75kW diesel generator with a 220V battery which is automatically switched on to supply the steering gear and other essential services should there be a failure in the main supply. The main generators supply the main switchboard through electrically operated circuit breakers and power is distributed through the main feeder section to master-boards and auxiliary boards. The emergency and main switchboards are interconnected.

The electrically driven refrigerating machinery was supplied by J. and E. Hall, Ltd., and the temperature of the cargo spaces is regulated by cooled air circulation. Long-distance electrical thermometers are fitted in each of the fan cooler rooms and provision rooms, and there is a multiple way indicator in the refrigerating machinery room.

The Stephenson Building

IN our last issue we briefly recorded the facts that H.R.H. the Duke of Edinburgh officially opened, on Wednesday of last week, a new building at King's College, Newcastle on Tyne, University of Durham. That building has been erected to accommodate the Departments of Mechanical and Marine Engineering and the Department of Agricultural Engineering. It is, as our engraving of its front shows, a handsome building, architecturally modern in design. It provides accommodation for a total of 650 students. Appropriately it has been named the Stephenson building, since it has been erected as a memorial to George Stephenson, of locomotive fame, and the inventor of the "Geordie" miner's lamp. For a time Stephenson lived within a stone's throw of the site.

After the opening ceremony we were able to inspect the building. But we do not intend to give a full description here of all the rooms and laboratories and their equipment. It will suffice to mention that the building consists of three main parts, the large five-storey main block that we illustrate and two wings, each of two storeys. The outer ends of the two latter are linked together by a narrow, two-storey structure, thus enclosing a small courtyard. Advantage of the island site has been taken to provide seven goods entrances, and all the laboratories are equipped with overhead travelling cranes, mostly of 5 tons capacity. Thus new plant, which it is necessary to provide if the equipment is to reflect advancing technical trends, can be easily brought in.

As is usual in such buildings, laboratories and workshops, which house heavy plant, are situated on the ground floor. On this floor, too, there are a number of small rooms specially

THE STEPHENSON BUILDING

designed for individual research projects. On a Mezzanine floor overlooking the large laboratories and workshops, as can be noticed in our engraving of the Heat Engines Laboratory, are situated a number of study rooms and class rooms for staff and senior students. These laboratories are mainly situated in the wings of the building. The lecture rooms, reading rooms and main class rooms are arranged on the first and second floors of the main block and the top storey is almost entirely occupied

HEAT ENGINES LABORATORY

by the large drawing-office, which is the subject of our third illustration. It will be seen that the building contains all the usual laboratories, lecture rooms, &c., that are to be expected in such a structure; and if some of the laboratories look rather bare at present it only means that there is space available to install the collection of new plant and new apparatus that will inevitably accumulate. What is peculiarly notable about the building is the convenience of its arrangement. It is obvious that a great deal of care and forethought has been put into its design.

In going around the building we noted several matters of interest. First of all we were pleased to notice that most of the equipment was small. If engines, compressors, pumps, &c., are large they are expensive to run and to test, a point of importance in days when money is scarce. Furthermore, since damage is very expensive to repair, students cannot be left to start up and to run such plant without careful and continuous supervision. Large plant looks impressive, but smaller plant is far more satisfactory for teaching purposes. Next we noted how in several departments special plant had been made for teaching purposes. One of the professors remarked to us, very truly, how seldom industrial plant, necessarily designed with other purposes in view, is really well-fitted to demonstrate engineering principles. That remark carries our thoughts to the workshop where equipment specifically designed for teaching can be made. It is particularly well fitted up with a variety of lathes and other tools and grinding, welding and flame-cutting equipment. Alongside there is a metrology laboratory and an instrument shop. This workshop, besides being intended to make equipment for the laboratories and for research purposes, has equipment sufficient for instruction and experiment in a production engineering course. One further point deserves mention. Electric power (a.c. and d.c.) is available up to 20 h.p. or 40 h.p. in all parts of the ground floor of the building from "test points" into which flexible leads can be plugged, an arrangement that keeps the floor more clear than usual of odd wiring.

In this new building the University appears to have model examples of what teaching laboratories, class rooms, drawing-offices, &c., should be. If in the future King's College, Newcastle fails to turn out year by year highly qualified engineers, Professor Burstall, head of the department of mechanical and marine engineering, and Professor M'Ewen, head of the department of agricultural engineering, will have no cause to blame lack of equipment or the inadequacy of teaching facilities.

DRAWING OFFICE

A Magnetic Store for High-Speed Digital Computers

In a paper presented to the Measurements Section of the Institution of Electrical Engineers by Professor F. C. Williams, Dr. T. Kilburn, and Mr. G. E. Thomas on November 20th, the authors described the elements and organisation of an experimental magnetic storage system for high-speed digital computers. A complete storage system of the kind described, with a capacity of 3000 numbers, each of forty binary digits, is incorporated in the digital computer at Manchester University (The Engineer, July 13th, 20th and 27th).

Explaining the concept of the intermediate store, of which the magnetic store is an example, the paper points out that calculations are performed in digital computers by transferring numbers to and fro between a rapid-access store and a computing unit—the whole operation being done in a manner set out in a table of instructions. The main requirement of such a store is that access to a particular piece of information contained therein shall be possible in a time comparable with that needed to do an elementary computation. There is no theoretical objection to supplying the whole storage capacity of the machine in this form. The practical objections, as quoted in the paper, are that available rapid-access stores are rather complicated and expensive and that a power failure results in loss of the stored information. The alternative to a rapid-access store of the full capacity demanded by the problem to be solved is a smaller rapid-access store backed by a slower access store of greater capacity, such as the magnetic store which is the subject of the paper.

Briefly the store consists of a rotating cylindrical drum coated with magnetic material. The width of the drum is divided into a number of tracks, each of which is scanned, as the drum rotates, by a "writing" and a "reading" head for imprinting and abstracting the stored information. A plated layer of pure nickel is used as the recording medium. The drum is run in synchronism with the fundamental frequency of the computer, under the control of a servo mechanism. A new method of digital representation (fully described in the paper) is used for the storage of data, and a low impedance head is used for the direct transfer of the data to the high-speed cathode-ray tube store of the digital computer.

In the design of the drum and its drive synchronism was considered to be very important, both because of the simplification of identity problems, and because it offered the highest possible reloading speed, and therefore the minimum of rapid-access store for a well-balanced machine. It was felt that synchronism would be more easily obtained with a rigid rotating drum than with somewhat elastic tape or wire fed from one reel to another, or even formed into a loop. These views were based on the expectation that about eighty digits could be stored per linear inch of the magnetic recording material. A superficial speed of the recording surface of about 70 m.p.h. would be required, combined with positional control of the surface, accurate to $\pm 0{\cdot}001$in under the recording head. These limits were set to ensure simultaneity of digit occurrence in the intermediate and rapid-access stores.

A drum with its cylindrical surface coated with magnetic material describes a revolution in the time occupied by the transfer of sixty-four forty-digit words. With due allowance for the five digits lost in the intervening black-out periods this time is

$$(40+5)\times 64\times 10 \text{ microsec} = 28{\cdot}8 \text{ millisec.}$$

This corresponds with a rotation speed of 2080 r.p.m., which is a convenient speed for

an induction-motor drive. The diameter, on the assumption of a packing density of eighty digits per inch, is approximately 11½in.

Rotation of the wheel moves the magnetic recording material under a vertically disposed set of recording heads; each head controls the magnetic pattern impressed on the peripheral track immediately beneath it on the wheel. Experience indicated that about thirty heads can be used per inch parallel to the drum axis, so that for a 2in depth of surface sixty-four tracks might be arranged. A drum of these dimensions has therefore a total storage capacity of sixty-four tracks, each holding sixty-four words of forty digits—a total of some 163,840 binary digits made up into 4096 words of forty digits. In the authors' limited experience this appeared an adequate size, bearing in mind that additional drums could be installed and paper tape could be used for further backing up. The identity of individual tracks could, of course, be established by selection of the appropriate individual head associated with the desired track; full synchronisation ensures word and digit identity.

The following description of the magnetic drum and the multiple recording heads is abstracted from the paper.

The Magnetic Drum

The wheel developed for the original experiments and for subsequent use in the computer is illustrated in Fig. 1. It is of 11½in diameter and 2in deep at the rim, and was machined from a centrifugal casting in bronze. The central hub contains a three-phase induction motor, consisting of an internal stator secured to the massive base plate at the bottom and by the gantry at the top of the axle. The squirrel cage rotor is secured internally to the hub of the wheel and rotates on two sets of thrust ball bearings at the bottom and top of the fixed stator axle. The 36in perimeter of the wheel accommodates the 2560 digits contained in one unit of the rapid-access cathode-ray tube store. There are a further 320 digit positions corresponding to the sixty-four black-out periods of the sixty-four numbers; these

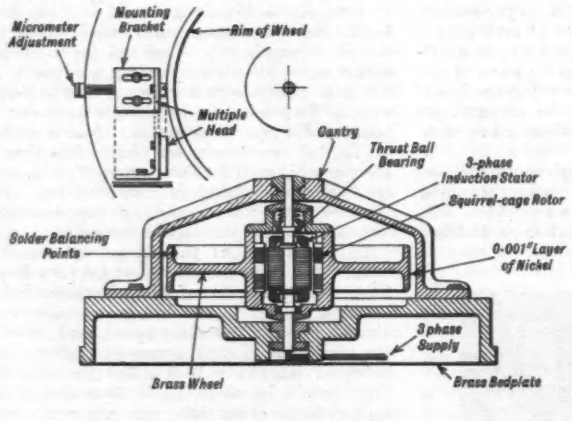


FIG. 1—MAGNETIC WHEEL

positions are wasted. The wheel rotates at a speed of 2080 r.p.m., constrained to nearly 1000 r.p.m. slip from the synchronous speed of 3000 r.p.m. by the eddy-current braking coils, which are mounted above the horizontal surface of the wheel. Each digit is therefore scanned in the required period of 10 microsec, and the complete unit of 2560 digits may be read in one revolution period of 28·8 millisec.

The recording heads are held in close proximity to the external rim of the wheel, which is plated with a 0·001in layer of pure nickel. The right-angle brackets employed to support the heads are illustrated in Fig. 1; they may be adjusted relative to the recording surface by means of the micrometer adjustments laid in the base plate. A working separation of 0·001in is maintained between the head and the recording surface; variation of this separation, due to eccentricity of the wheel or to vibration of the mountings, will produce modulation of the amplitude of the pick-up signal. To eliminate these defects, the wheel has to be turned to an accuracy of less than 0·001in in the 11½in diameter—an operation which limits the width of the rim in the present case to 2in. If the diameter is reduced, then it is possible to extend the width of the recording surface. To ensure absence of vibration the massive base plate and rigid mounting is employed, while the wheel is dynamically balanced on high-quality bearings. The wheel constructed in this manner is found to be almost vibrationless and to run smoothly for long periods without attention.

Multiple Recording Heads

The principle of the single-wire head design of Dr. Booth was found to be satisfactory and to lend itself readily to the particular design requirements of our system. It is necessary to supply separate heads for the processes of reading and writing, with the reading head advanced by at least 0·007in relative to an identical writing head. This separation between reading and writing heads must be accurately controlled and, when a number of double heads are used, the separation must be constant within the limits ±0·001in.

The small-iron-path principle of the Booth head was employed in the construction illustrated in Fig. 2. A single "double-head" unit consists of a central lamination *B* of Radiometal, to both sides of which are pressed cupped laminations *A* and *C*. A single wire is threaded through each of the triangular cups formed between *A* and *B* and between *B* and *C*. Two thin paper separating pieces prevent actual contact of the three pole-pieces and define a gap of width 0·001in in the actual recording face of the head. The two gaps in the recording face satisfy the dual requirement of a reading and writing head. If the writing current is passed through the right-hand wire, flux will flow in the closed magnetic circuit formed by the *B* pole-piece and the *C* pole-piece. At the gap in the circuit, a fringing field of flux will be produced, which, owing to the sharp edge presented by the *C* pole-piece to the *B* pole-piece at this point, will be a considerable proportion of the total flux which passes between the two pole-pieces. This fringing flux will assume a path in the magnetic medium which is moving past the writing gap, and a magnetic pattern will be recorded.

The flux produced by this recorded pattern will couple with the magnetic circuit formed by the pole-pieces *A* and *B* around the left-hand wire. The extent of this coupling will again depend on the characteristics of the air-gap in the magnetic circuit. Flux developed in this circuit will induce a voltage in the reading wire and a signal approximating to the time derivative of the flux distribution in the magnetic circuit will be obtained. If the magnetic medium is assumed to move from left to right, the reading gap may be considered as phase-advanced with respect to the writing head. The amount of this advance is controlled by the width of the central pole-piece *B*. In practice, a separation of 0·015in is required, and it is obtained by using a single lamination *B* of the required thickness.

The outer pole-pieces *A* and *C* are only 0·005in thick, so that an extra brass boundary-piece 0·02in thick is added to protect the assembly, which is securely clamped at the base of the laminations. To multiply the construction, each of the five components is cut before assembly with a series of equidistant slots, so that each has the form of a comb with a series of teeth equal in number to the number of heads it is required to fashion in one block. The five slotted laminations are assembled in the correct order, and separate wires are threaded through both the "read" and "write" sides of the total number of heads formed. These wires are brought out through

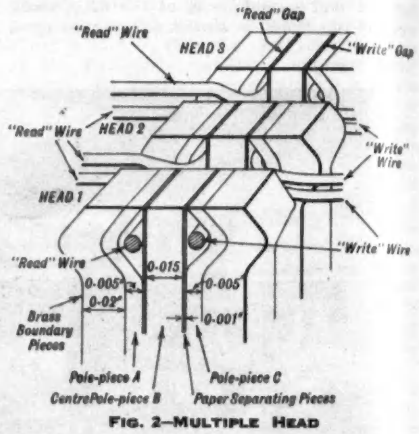


FIG. 2—MULTIPLE HEAD

the spaces between adjacent heads as illustrated in Fig. 2.

The width of the recording surfaces on the wheel is 2in and a series of multiple heads based on the design described above have been constructed in blocks 2in long. As experience was gained, the number of heads per block was increased from nine to thirty-two. The latest development is a block of thirty-two heads, each head being separated from its neighbour in the block by a distance greater than the width of one head. It is therefore possible to interleave the tracks of two blocks of heads on one wheel, giving a total storage capacity of sixty-four tracks per wheel.

In the models of the thirty-two-head construction so far tested, mechanical failure in the complicated wiring connections is restricted to two units in the thirty-two; it therefore seems possible that, when the design has been further standardised, a reliable form of construction can be achieved with these dimensions. The magnetic properties of the separate head units are entirely satisfactory, as the amplitude of the pick-up signal is high above the noise level. It would therefore appear that the limit in size reduction has not yet been reached. A further decrease in scale seems possible, though the problem of multiplicity of connections in such a small space, and the percentage of head failures in the composite construction, merit consideration relative to that of an individual type of head assembly.

The specially designed mounting brackets illustrated in Fig. 1 are employed to ensure that the recording face of the head is held parallel to the 2in recording surface. A clearance of 0·001in is maintained between head and wheel.

When it is required to interleave two blocks of heads, vertical adjustment of one of the blocks is necessary. This adjustment is obtained by means of a vertical micrometer attached to the upright face of the mounting bracket.

The Royal Mint.—The report for 1949 of the Comptroller of the Royal Mint states that 455,778,650 coins of fifty-five denominations were passed during the year. Three-fifths of the year's production of coins was for Commonwealth and foreign Governments. The report notes also that, at the end of 1949, the value of silver and cupro-nickel coins in circulation in the United Kingdom was estimated at £145,200,000.

Potash in N.E. Yorkshire.—In a statement accompanying the annual report of Fisons, Ltd., the chairman, Mr. F. G. C. Fison, says that the company has continued its exploratory drilling for potash in N.E. Yorkshire with satisfactory results. The indications are that a considerably wider field can be worked for potash than had previously been thought possible. A comprehensive report is now being prepared for submission to the Government.

The Supply of Electric Lamps*

CONCLUSIONS AND RECOMMENDATIONS

THE E.L.M.A. [Electric Lamp Manufacturers' Association] system, on the manufacturing side, presents to-day the following picture, which is a simplified outline of the complicated arrangements described in detail earlier in the report. The companies which constitute E.L.M.A. are bound together in what they themselves describe as "in certain respects a partnership," which is not dissoluble until 1955, and in which two senior partners (G.E.C. and the A.E.I. Group) play a predominant role. These two are between them responsible for over half of the production of lamps by the members of the E.L.M.A. and work very closely together in all matters concerned with lamp production: they take the initiative in E.L.M.A.'s price-fixing activities and they jointly own the factories making bulbs and caps which supply most of the other members' needs as well as a considerable part of the requirements of the controlled companies and independent manufacturers. Patents, which have been, and as regards fluorescent lamps still are, of great importance in the industry, are mostly controlled by a few members, including particularly G.E.C. and the A.E.I. Group, but are made available to most of the others. Six of the E.L.M.A. members undertake a certain amount of research, but most of this is done by G.E.C. and B.T.H. in friendly rivalry. The results of this research, and other manufacturing knowledge, are passed on to the other members, except Crompton,[1] B.E.L.L. [British Electric Lamps, Ltd.] and Aurora. Members at present have access also to patents, research and manufacturing experience originating in the United States and Holland. A rapid and comprehensive exchange of information about new developments, as they occur, has encouraged the more rapid application of new discoveries and must also, we believe, make more effective the efforts of individual research departments. We have noted the invention of fluorescent lighting and the technical advances made in production methods by E.L.M.A. members. Although we have recorded our opinion that prices were unduly high before the war, none the less it is only fair to record also that much of the benefit of this technical progress has been passed on to the public in a progressive and substantial reduction in the prices of lamps; in the case of general service filament lamps this trend has continued even during the last twelve years, when prices of most other goods have been rising, though we have noted (in paragraph 202) the circumstances in which these more recent reductions of price were made. We call attention also to the rise in putput per man-hour (paragraph 214).

E.L.M.A. members manufacture only such types of lamps (a very wide range) as E.L.M.A. sitting in council agrees upon. The Council fixes the price at which each type is to be sold by all the members who make it, and by laying down the prices to be charged by distributors E.L.M.A. ensures that uniform prices are charged at any given stage of distribution. Each E.L.M.A. member, therefore, forgoes any competitive advantage he might secure over other members by fixing lower retail prices or giving larger discounts to distributors, by developing different types of lamp, by ownership of patents or new discoveries, or by superior manufacturing methods. Competition, is, in practice, confined to advertising and salesmanship. Though each is selling his lamps under his own brand, all members, so far as any given type is concerned, are selling practically identical lamps at a common price.[2]

Each E.L.M.A. member is free to secure as many orders as he can for any approved type of lamp. The principle of the sales quota system as inherited from Phœbus,[3] however, is that each member is entitled only to a fixed percentage of the total trade in E.L.M.A. lamps of all kinds taken together, on the ground that all are entitled to share *pro rata* in any change in the level of the trade of the members. Any member who sells more than his quota has to make a compensatory payment and any who has sold less than his quota receives a compensatory donation. There is no restriction on the total number of lamps of all kinds sold by E.L.M.A. members, and the total volume of production is free to grow or diminish according to the demands of trade.[4] Under the provisions of two international agreements, imports from the American G.E.C. and its subsidiaries are excluded and imports from Philips (Holland) are limited.

This short general description relates to the present position. If the picture had been painted in 1939 it would have shown a very much greater degree of restriction both in the practices and in the policies of the members of E.L.M.A. We are not asked to say whether the conditions restrictive of competition in the supply of lamps have operated against the public interest in the past, but whether they do so now or may be expected to do so in the future, and for this purpose it is necessary to record the change which has come over the E.L.M.A. system in the last few years, and to consider to what extent this change may be expected to be permanent.

We note, as regards the price reductions made during and since the war, that they were made either at Government request or in response to public policy in relation to monopoly, that the new patent policy has avowedly been evolved in the light of the new Patents Act and the Monopolies and Restrictive Practices (Inquiry and Control) Act, and that, in the period of shortage of bulbs during and since the war a Government allocation scheme has operated. Moreover, old Phœbus ideas of a very restrictive kind are certainly not dead. In all the circumstances we do not feel that the present improved state of affairs could be relied upon to continue if the E.L.M.A. system were left without considerable amendment and additional safeguards in the public interest.

We see considerable advantage in the exhange of technical knowledge within the industry and much force in the argument that it could not continue if there were price competition between the companies concerned. The manufacturers' price ring, therefore, has this advantage to offset its potential dangers. We note also that the prices fixed under it are now on average moderate in relation to costs and that there is at present a considerable measure of efficient independent competition; we estimate that 27 per cent of filament lamps are supplied by independent manufacturers and 13 per cent by the controlled companies and that, in the case of fluorescent lamps, the independent manufacturers supply between 30 per cent and 40 per cent.[5]

On balance we see no sufficient reason why the E.L.M.A. system should be completely broken up, but we think that the system may be expected to operate against the public interest in the future unless considerable changes are made and additional safeguards for the public interest provided, as described in the next paragraph. Given these, we do not recommend that the members of E.L.M.A. should be prohibited from continuing to fix minimum manufacturers' selling prices for agreed types of lamp sold by them to wholesalers, to retailers or to users, provided two conditions are fulfilled. These are first, that the E.L.M.A. members should take steps to ensure that the system of exchange of technical knowledge extends to all manufacturers who are within the system of common prices; and second, that the level of the prices fixed by E.L.M.A. should be reasonable. We think that the Government should review the prices from time to time. This is our present recommendation as regards the system of common prices; for the future we record our view that if at any time changes occur which substantially reduce the degree of competition with E.L.M.A. which we advocate in the following paragraphs it will be necessary for this whole question to be examined afresh.

Our recommendations for changes in the system and for safeguards on the manufacturing and on the distributive side to maintain and strengthen effective competition are given below; we list them together here because, though each is dealt with in turn later, the practical effect of each cannot be considered in isolation. In summary they are:—

(i) That E.L.M.A. should undertake that members who sell lamp components (other than patented components and ready-coiled filaments) will make them equally available to members and non-members at prices which shall not be higher to non-members than to members;

(ii) That, if the working of the new patent policy results in an appreciable reduction of the degree of competition to which E.L.M.A. is subjected, the whole question should be examined afresh;

(iii) That the E.L.M.A. members should give an assurance that the controlled companies will continue to provide a measure of competition as suppliers of cheap lamps, and that they will not be used as fighting companies;[6]

(iv) That the sales quota system should be brought to an end;

(v) That E.L.M.A.'s rules about type "B" lamps should be altered to remove quantity and quality restrictions;

(vi) That the arrangements for exclusive dealing and aggregation of quantity rebates should be brought to an end;

(vii) That payments to associations of distributors should be brought to an end;

(viii) That the enforcement of resale price maintenance by means of the collective sanctions of fines and the stop list should be brought to an end;

(ix) That E.L.M.A.'s rules should be altered to permit other distributors as well as co-operative societies to give "dividends."

REFERENCES

[1] Crompton obtained such information in the discharge field until the end of 1949 (Appendix 10 of the Report).

[2] There is a certain amount of manufacture by members of other members' branded lamps and, indeed, provision is made for this in some of the agreements between members. E.L.M.A. has told us that in other parts of the Commonwealth there are jointly owned factories, each of which regularly produces lamps bearing the various members' brands.

[3] An agreement (1924) whereby the main lamp manufacturers of the world undertook (*inter alia*) to regulate their trade outside North America by preserving the *status quo* in any given territory by means of percentage quotas.

[4] Except to the extent that the obligation to make compensatory payments may indirectly restrict the output of individual members.

[5] As we explain (in Chapter 13), these percentages are only approximate. We think that filament lamps are supplied to the home market roughly in proportion to production, as between the three groups of manufacturers; the controlled companies' share of the home market for general service filament lamps, however, is almost certainly higher than 13 per cent. As regards discharge lamps, the independent manufacturers have a bigger share of output than of sales in the home market because they export more of their products, relatively, than the E.L.M.A. members.

[6] i.e., companies which, as a matter of policy, sell lamps regardless of cost, specifically in the markets of independent manufacturers.

* Abstract. "Report on the Supply of Electric Lamps," by the Monopolies and Restrictive Practices Commission. His Majesty's Stationery Office. Price 6s.

Electro-Mechanical Converter Instrument

A NEW instrument for measuring mechanical quantities electrically and for giving remote indication of the results has been developed by the research laboratories of the General Electric Company, Ltd., and Salford Electrical Instruments, Ltd.

The system has a very wide range of industrial applications, involving the measurement of force, pressure or displacements such as gas, liquid and steam pressures; liquid levels; compression or tension in structural members; pressures in rolling mills and presses; valve indication at remote points, and elongation measurements.

Operation is from a.c. mains and the indications can be transmitted directly over several miles. The basic principle of the system is that of a change of inductance in a circuit, and the makers believe that the inherent difficulties of earlier change-of-inductance systems, due to magnetic leakage, temperature errors and poor electro-mechanical efficiency have been overcome by the use of a new magnetic powder material "Gecalloy PL." The powder is moulded and used as the magnetic circuit of an electro-mechanical transducer, which can be regarded as an electrical transformer with a

core that is moved by the originating mechanical force (Fig. 1). The primary winding of the transformer is connected to a.c. mains through a step-down transformer, and the secondary winding is connected to a special dynamometer type indicator. The mechanical force on the movement is transferred to the cylindrical magnetic core in the centre of the unit, and this core can be moved over a total distance of about 0·1in from a central position inside the

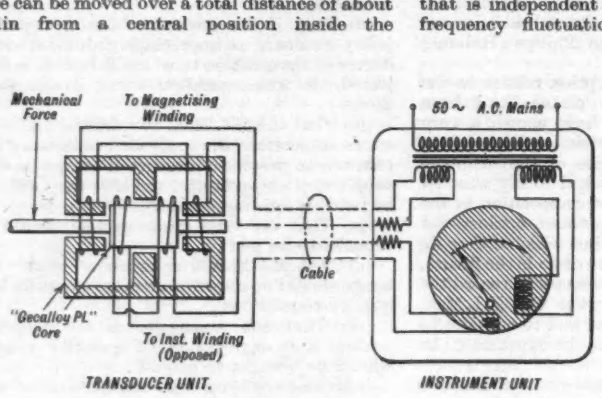


FIG. 1—DIAGRAM OF ELECTRO-MECHANICAL CONVERTER INSTRUMENT

secondary windings. The secondary windings are balanced and the current is zero when the core is central, but will increase proportionally as it is displaced.

The coils in the converter are connected so that the magnetic flux flows through the core in the same direction as the very small external leakage flux. This makes it possible to house the core in a closely fitting metal tube which ensures robustness and avoids losses and differential temperature errors. The secondary windings of the converter are placed on the inside of the unit and are connected in opposition, after careful balancing, so that the voltage induced in each is neutralised when the moving core is exactly central. Alternatively, the core can be displaced a fixed amount and the windings altered so that the full travel of the core from one end of the gap to the other can be used to increase the range of the instrument. If desired, the core in the centre position can be

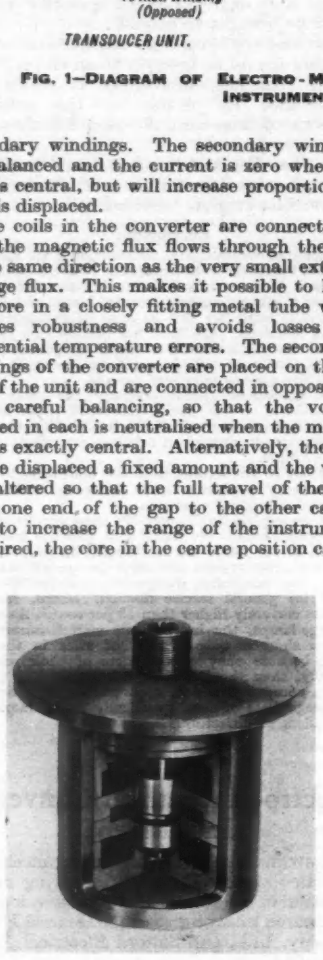


FIG. 2—SECTIONAL VIEW OF THE CONVERTER UNIT

connected to a centre-zero instrument so that differential measurements can be made.

The converter (Fig. 2) is an aluminium alloy case about 5in long, with the operating spindle projecting through the centre of one end. The unit is sealed and is free from temperature error, so that it can be installed in exposed positions. It is connected to the indicator by a four-core electric cable sealed to the side of the unit. The two instruments together (Fig. 3) weigh less than 40 lb and the indicator can be installed at any distance from the transmitter.

The indicating instrument is of similar construction to the standard moving coil switchboard instruments and is normally a flush mounting protected assembly with a 100 deg. scale. It is intended that instruments with 270 deg. scales should be available later.

The movement of the instrument is operated by an a.c. electro-magnet. The resulting torque for the instrument is appreciably greater than that of a comparable d.c. moving coil instrument.

It is important to note that the combination of the converter unit and this special instrument is necessary to give an electrical performance that is independent of a.c. mains voltage and frequency fluctuations. Hence, neither the converter nor the instrument have practical applications when used separately. The electrical system is, in effect, a method of measuring mutual inductance of the converter in which the instrument movement and electro-magnet are an essential part of the circuit.

Although the equipment described above deals with the converter unit as a separate entity, certain kinds of mechanical equipment, such as pressure gauges, are being manufactured or developed with built-in converters. In these instances the electrical equipment is supplied separately so that it can be adapted by the user.

This new system is simple and robust and can be operated and maintained by unskilled personnel. Its overall accuracy is high and is unaffected by variations of ambient temperature. Up to 30 per cent change of voltage and

FIG. 3—CONVERTER UNIT WITH THE ASSOCIATED INDICATOR

10 per cent change of frequency can be tolerated without the indications being affected, and neither of these extremes is likely to occur in practice. Power consumption is very small and there are no amplifiers to maintain, contacts to keep clean or a multiplicity of moving parts to give trouble. Quantities being measured can easily be summated, multiple indicators can be used, and the inclusion of alarms, servo mechanisms or recorders presents no difficulties.

THE CRAFTMANSHIP OF GOLD COINING.—It may be recalled that in 1949 the Royal Mint struck a number of gold sovereigns in order to preserve inherited knowledge and craftsmanship, since gold coining requires a different technique from coining in other metals, and greater precision of workmanship. It is now stated that a further minting is to be started shortly at the Royal Mint. The coins, as before, will be struck from existing dies (year 1925, bearing the head of King George V) and will consequently not be distinguishable in date or design from earlier issues. There is, of course, no question of issuing these sovereigns for circulation and they will remain part of the gold reserve. A sovereign weighs 7·98805 grammes, the proportion of pure gold being 91·6666 per cent, or 22 carats. The value of the gold content at the present price of gold of £12 8s. an ounce is £2 18s. 4d. Because of the high value the tolerances in the case of gold coins are smaller than in other cases and greater precision of workmanship is thus demanded.

Shortcomings of Structural Analysis*

By Professor J. F. BAKER, O.B.E., M.A., Sc.D., D.Sc.

A MEMORIAL lecture to be complete and satisfactory must deal with a subject not only of value in itself but linked in some way with the distinguished man who is to be remembered.

A great deal of nonsense has been written in the past about the gap between theory and practice. The engineer whose business it is to create, to make something, is essentially a practical man, but this does not mean that he is not interested in the scientific aspect of his subject or in theory. In the early, less complicated, days the engineer was his own research worker; there was then no conflict between theory and practice because it was the so-called practical man who was urgently deriving and checking theories which would enable him to press on with greater works more quickly than simple empirical methods would allow. Though the somewhat artificial pressure of to-day often prevents the engineer from conducting his own research the position is still the same in most industries and most branches of the profession. It may well be that the urge to use new methods and new processes could be stronger but there are too few cases of important developments brought to light by the theoretical worker and neglected by the practical man to justify the suggestion of conflict between practice and theory.

During the past twenty years greater advances have been made in the elastic stress analysis of structures than in any other branch of applied mechanics. Before that time it was possible, and then only with great labour, to deal with a structure of not more than about twelve degrees of redundancy, so that the primary and secondary stresses in most practical structures could not be determined. Now there are virtually no insoluble theoretical problems and engineers are quite prepared to undertake elaborate calculations of the stresses in their structures as a check on design. The question to be considered is how far this application of advanced theory is justifiable.

If in these twenty years advances had been made in mathematical analysis alone it would not be easy to examine the question that has been posed. Fortunately experimental methods have also advanced, so some data are available of the strains in actual full-scale structures from which observed stresses can be deduced to compare with those calculated. These experimental data cannot be obtained reliably from tests of small-scale model structures since such models are likely to be idealised owing to the difficulty of reproducing on the small scale all practical details. Small-scale structures can often be tested usefully to provide a mechanical analysis of stresses more economically even than modern mathematical methods allow, but it must be remembered that one cannot get out in the answer more than one put in when stating the problem.

The simple elastic theory can be depended upon to give values, sufficiently accurate for design purposes, of the stresses due to any load system in members of a structure in which the characteristics of the connections are known, the members are without imperfections and perfectly straight, or if initially curved, where the magnitude of the curvature is known. Elastic analysis can give, therefore, for an existing structure in which departures from straightness and the characteristics of connections can be measured, an accurate estimate of what are often called the primary and secondary stresses.

One thing that always delights me is the accurate results obtained by making use of Bernoulli's simple assumption that in a beam a plane cross-section at right angles to the plane of bending before strain remains plane after strain. The calculation of stresses in a structure can only be determined accurately at sections not in the immediate neighbourhood of joints or applied loads because, what is

* North-East Coast Institution of Engineers and Shipbuilders. The Twentieth Andrew Laing Lecture, November 9th. Abstract.

often forgotten by the designer must now be remembered, that in the stress analysis of structures we always rely on Saint Venant's Principle, which states that forces applied at one part of an elastic structure will induce stresses which, except in a region close to that part, will depend almost entirely upon their resultant action and very little upon their distribution; or more crudely, that at the points of application of loads, at supports and at joints, there are concentrations of stress and irregularities of stress distribution sensitive to small differences in the conditions at these points, but that at distances equal to about the depth of the member the effects of the small differences disappear and the stress distribution depends only on the resultant action, the bending moment, shear force and so on. We rely on Saint Venant's Principle and usually ignore what happens close to the joint or load because it is far too laborious and difficult to do anything else, but this must not blind us to the fact that the local or tertiary stresses at these places are apt to be high, and that at them also the primary and secondary stresses often have their greatest values. But, forgetting for the moment these tertiary or local stresses, it can be said again that the power of analysing primary and secondary stresses is of little use to the engineer faced with designing a structure by a permissible stress method because, before it is designed the characteristics of the connections and the imperfections of the members will not be known. The only estimates of these properties which the designer can make are likely to be so far from the truth that elaborate stress analysis is unjustified.

This statement needs support. It can be obtained from an examination of the elastic stresses developed in a real structure. My first example is the straightforward case of a two-bay, three-storey steel frame made up of the same 8in by 4in by 18lb "I" section throughout (Fig. 1), the feet of the three stanchions being firmly fixed in a concrete slab and the beams being connected to the web of the stanchions by means of the familiar stool and top cleat connections made up of 3½in by 3in by $\frac{1}{16}$in angle, 4in long, bolted to the members with ½in diameter black bolts. This structure was subjected to a concentrated vertical load of 2 tons applied to the centre of each beam in turn, and strain measurements were made at sections some distance from the connections to avoid local stress concentrations, so that the maximum longitudinal fibre stresses due to the bending of the stanchions in the plane of the frame could be deduced from the observations. The structure was, of course, built to be symmetrical about the stanchion *E*. It was to be expected, therefore, that the stresses in that stanchion would be the same whether beams *D E* or *E F* were loaded. This was not found to be the case. The most striking differences occur at sections E_2E_1 and E_2E_3 where, when the load was on beam D_2E_2, the stresses were 5130 lb and 5220 lb per square inch, whereas when the load was on beam E_2F_2 they were 3300 and 3550 lb per square inch.

The observed stresses satisfied all the checks of equilibrium to within 100 lb per square inch and so were deemed to be accurate to that limit. It was suspected that the discrepancies were due to slight differences in the behaviour of the beam to stanchion connections arising from practical imperfections. This was verified by the laborious process of measuring the actual characteristics of the connections and carrying out an elaborate analysis allowing for them, the results of which agreed closely with the observed stresses. No special precautions had been taken in erecting this apparently symmetrical frame so it was decided to re-erect it as before, using the same connections but having the bolts all tightened by the same erector, using a 10in spanner. The results are even more alarming. While there is now fair agreement in the greatest stresses due to loads on beams D_2E_2 and E_2F_2, those produced by loading beams D_1E_1 and E_1F_1, which were satisfactory in the first test, fail to agree. While in the first test the greatest percentage difference was 55·5 per cent, it has now risen to 138 per cent. To see what improvement could be obtained under most carefully controlled conditions the frame was re-erected with entirely new bolts and cleats and a special spanner was made which would tighten the ½in diameter bolts with a torque of 600 lb in to within 5 per cent. Even with these quite impracticable refinements, differences of the order of 25 per cent were observed in the greatest bending stresses.

Similar discrepancies have been observed when testing actual building structures. A particularly straightforward case was found when investigating the behaviour of the Cumberland Hotel, London. A single-bay frame there appeared to be symmetrical in every way. When symmetrical loads were applied to the beam, however, the bending stresses in the two stanchions were not the same, the discrepancies at different floor levels varying from 4 to 30 per cent. Here again they arose almost certainly from differences in the apparently identical beam-to-stanchion connections.

An example of the other kind of shortcoming in elastic analysis, the high and uncalculated stress near a support, was also found in testing this particular frame in the Cumberland Hotel. The squared end of each stanchion was held down to a 14in by 10in steel slab

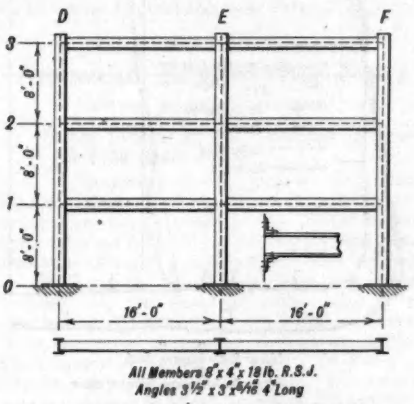


FIG. 1—*Experimental Steel Frame*

5in thick by four 1in diameter bolts. The stanchion was a 12in by 8in B.S.B. with 8in by ½in flanged plates. Four strain gauges were attached one at each corner of the stanchion at such a distance, 12½in above the top surface of the slab that there was reasonable expectation that Saint Venant's Principle would be obeyed. A load was applied to a beam in the structure subjecting the stanchion to an axial load and some bending about its major or *XX* axis and strain measurements were made. The observed stresses deduced from these measurements showed that the stress at one corner of the stanchion was seventeen times as great as at any other corner.

Many of the discrepancies in the stresses in the framed structures to which reference has just been made can be blamed on the vagaries of fairly flexible riveted or bolted beam-to-stanchion connections. An obvious way of avoiding them, it might be thought, would be to use rigid connections. Owing to the difficulty of making stiff riveted joints, rigid connections to-day are almost synonymous with welded connections. Even with these a perfectly rigid joint is not easily obtained but where we are considering a construction which will make the stresses under working conditions close to those given by design calculations, welding adds a different but very considerable complication. This is because residual stresses and reaction stresses are introduced. Many investigators have determined the magnitudes of the strains due to welding and it is now generally recognised that the sum of reaction stresses and residual stresses will normally reach the yield point stress of the parent material in the vicinity of the weld, even if the rigidity of restraint is not very severe. It is justifiable to assume, therefore, that the yield stress has been reached in the welded joints of all structures before any external load system has been applied. In saying this it is not my intention to bring any discredit on welding, which seems to me the rational method of fabricating structures. It must be remembered that residual stresses are also developed in the production of rolled steel joists by cold straightening or bending, punching, machining and similar processes, so they are likely to be found in all steel structures. Though more prominence has been given to their presence in welded fabrication there is probably little to choose in this respect between riveted or bolted and welded structures.

Let us consider now another form of structure, the ship, which will doubtless be of greater interest to many of you. Since the ship is nothing more than a beam it is not surprising to find that the longitudinal stresses observed agree reasonably well with those calculated by the conventional beam theory. This can be seen from Fig. 2, which gives, compared with the calculated, the longitudinal stresses due to a hogging bending moment observed in the still-water trials on the M.V. "Newcombia" conducted some years ago for the Admiralty Ship Welding Committee. This diagram does not show the greatest stress at each point in the cross-section but merely the heart-of-plate stresses deduced from the skin strains measured. Even these show fairly marked discrepancies in the longitudinal bulkhead. To these heart-of-plate stresses must be added the local bending stresses which in the "Newcombia" amounted to as much as 13 tons per square inch on the starboard longitudinal bulkhead, that is, an additional stress much greater than the heart-of-plate stress. On top of all these there were, of course, stress concentrations around hatch openings and elsewhere, the concentration factor, that is, the ratio of observed to beam theory stress, varying from about 1·6 to 1·3. These ratios are relatively small. In other ships there are records of stress concentrations due to structural discontinuities of the order of 2·5 to 3·0. Nominal stresses exceeding 5 tons per square inch are to be expected at sea under certain conditions of loading, so it is clear that high additional stresses may be present. Even in the ship, therefore, the simple elastic theory gives only a fair estimate of the heart-of-plate stresses due to changes in load and gives no real indication of the total stresses due to change in load. It must also be remembered that before any loads are applied, the ship structure like most others will have reached the yield of stress of the material at many critical points, due to the presence of residual and reaction stresses. It may be worth reminding you, in this connection, that measurement of residual stresses in a welded tanker during construction, recently reported to the Chesapeake Section of the Society of Naval Architects and Marine Engineers, showed the existence of stresses of the order of 8 tons per square inch at points far removed from any weld.

These few isolated examples do not provide conclusive evidence of the uselessness of elastic analysis as an aid to the designer, but they are typical of the great mass of data which is available and which has convinced me that, so sensitive is the redundant structure in the elastic range to small imperfections and variations inevitable in practice, that the designer is wasting his time when he embarks on an elaborate elastic analysis. My conclusion is that the elastic behaviour of practical structures is too complex and variable to enable the designer to make any real advance by this means.

This conclusion would be depressing if the engineer had no other means than elastic analysis of determining the strength of his structure. Fortunately, while it is impossible to determine accurately the load which a structure can carry without exceeding somewhere a permissible stress, it is possible in the case of structures made of a ductile material, such as mild steel, to determine with surprising accuracy, the real strength of a structure, that is the load at which it will fail or develop embarrassingly large deflections. This is possible by admitting and taking full account

of the plastic behaviour of the material. To enable the engineer to make his calculations, a simple plastic theory of bending has been developed.

The theory is nothing more than an extension of the simple elastic theory and holds for all bending moments less than the yield moment under which the yield stress of the material is reached in the extreme fibres. The beam is capable of sustaining a greater bending moment, but, in order to deduce the corresponding stress distribution, it is necessary to consider the nature of the stress-strain relationship of the material beyond the yield point. This depends on the composition and history of the steel. After yield, there is a range of pure plastic deformation with no increase of stress, until strain hardening occurs at a strain of from eight to twenty times the strain at yield. The pure plastic range is usually sufficient to enable considerable deformations to take place before strain hardening has any significant effect. It is therefore reasonable to assume that after the yield stress has been reached in any fibre of a beam under increasing bending moment, the stress in the fibre will remain constant. After this process has been carried some depth into the beam the stress distribution will therefore be that which corresponds to a moment of resistance somewhat greater than the yield moment. The maximum moment of resistance is obtained when the whole section has been strained beyond the yield point, its value then being referred to as the full plastic moment.

The stress distribution corresponds to theoretically infinite curvature and therefore when the full plastic moment has been reached at any section of a simply supported beam, the deflections become indefinitely large, and collapse is said to occur, though it is well to remember that if the load were reduced a little it could be supported quite safely.

It may be clearer if we consider here what happens to a simply supported beam carrying a central concentrated load. As the load is increased to a certain value the load-deflection curve is linear and the yield stress is developed at the centre of the beam under this load. As further load is added yield penetrates up and down into the section and also along the beam, forming plastic zones. The beam can support additional load until these plastic zones meet, when a plastic hinge forms at the centre of the beam. It is like a rusty hinge since the full plastic moment is maintained while the deflections and rotations grow large and this is, of course, the essential part of the phenomenon. We know that this picture of what happens under a concentrated load is over-simplified since the effect of shear, among other things, has been neglected.

If the ends of the beam are encastré, collapse cannot occur until the beam has become a mechanism by the formation of three plastic hinges, that is until the fully plastic moment has been reached at three sections. Consider a fixed-ended beam subjected to a uniformly distributed load; in the elastic range the bending moments at the ends will be twice that at the centre so that yielding will begin at the ends of the beam. As the load is increased zones of yielded material will develop at the ends of the beam until full plasticity has been reached at the end sections. As the load is further increased the end bending moments will remain constant at the full plastic value, and at a certain stage yield will occur at the centre. At the same time relative rotations will take place between the ends of the beam and the rigid supports. Collapse will finally occur when the central section also becomes fully plastic. It is easy to deduce that, whatever the cross section of this uniform beam, the load causing collapse is one-third as much as that which produced the first yield at the ends of the beam. Elastic-design methods, therefore, do not take advantage of the full additional strength obtained from end fixity. It follows that if there are two beams in a structure, one simply supported and one encastré, both designed by the usual working-stress method for the same design load, then the latter will be capable of carrying one-third more load before collapse than the former. For static loads when strength is the design criterion, this is indefensible. If the load factor, that is to say, the ratio of the load causing collapse to the design load, enjoyed by the simply supported beam is adequate, why should it not be used for the encastré beam with a resultant economy of material?

We have at Cambridge recently carried out a number of tests on small square beams ¼in side prepared from 1in square bars of rolled mild steel in the "as received" condition. In the first, the ends of the beam were fixed as rigidly as practicable. A central concentrated load was applied and collapse occurred when the load reached the magnitude of 258 lb. The ends of this beam were fixed as well as possible but they were not completely encastré, since the ratio of end moment to central moment while the beam was still elastic was 0·912 instead of unity, as it would have been had the ends been completely fixed. Now this

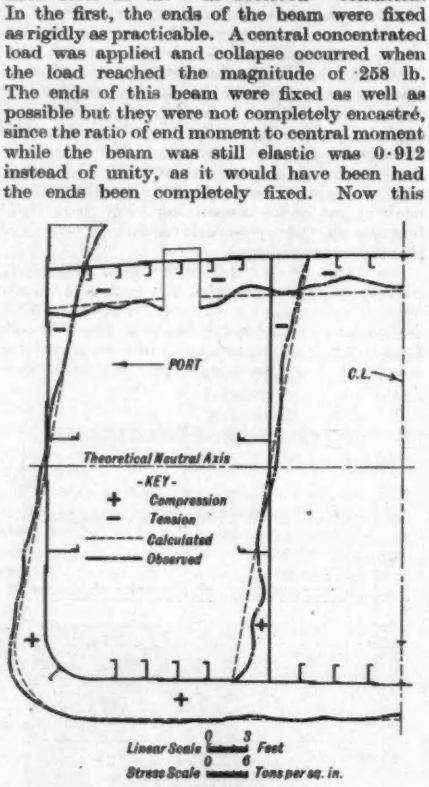


FIG. 2—*Observed and Calculated Stresses in M.V. "Newcombia"*

lack of complete fixity which makes nonsense of exact elastic analysis has no effect on the collapse load of the structure so long as the ends of the beam are so attached to the abutments that the full plastic moment of the section can be developed. This was shown by repeating the test with beams connected to the abutments with different degrees of fixity.

While it is not difficult to show theoretically that relative sinking of supports has no effect on collapse load, it may be more convincing to illustrate the point from the results of tests. Two-span continuous beams were subjected to concentrated loads. In the first test the supports were at the same level; the loads were increased until collapse occurred and this happened at 1·138 tons, whereas the calculated collapse load was 1·152 tons. The test was repeated on a similar beam but this time the central support was lowered by 0·465in, a distance so chosen that the yield stress would be reached in the extreme fibres between the loads before contact was established with the central support so that, according to elastic theory, the beam would have failed when this occurred under a load of about 0·3 tons. Real failure or collapse did not occur here. At the point when the beam came into contact with the support the rate of growth of deflections decreased; thereafter the deflections did not become large until the beam collapsed at 1·125 tons, which is close enough to the 1·138 tons determined for the first beam to show that sinking of supports has no effect on the collapse load of a ductile beam.

Many structures of various kinds both small-scale and full-scale, have been tested under complex loading conditions and the simple plastic theory has proved itself in every case to be a sound basis for estimating the useful strength.

As all the tests so far described have been on small-scale beams it may be more convincing to conclude this part of the evidence with a short account of the behaviour of full-scale structures. A number of rectangular portals having spans of 16ft and heights of 8ft built up of 8in by 4in joists have been tested. One with fixed feet and a vertical central load and a horizontal load at the level of the beam were applied. In the first test on a similar portal but with pinned feet the horizontal and vertical loads applied were kept equal and it was calculated that collapse would occur when each load was 5·65 tons. As the test loads were slowly applied definite signs of creep were detected at about 4 tons but the structure continued to support load until 5·75 tons had been reached, that is only one-tenth of a ton more than the calculated load, when the side-sway deflection was observed to be increasing rapidly and after about three minutes the frame collapsed. As it was failing it was observed to move rapidly through a distance of approximately 1ft in the horizontal direction before the leeward stanchions became unstable and deflected laterally.

Such extraordinarily close agreement between observed and calculated collapse loads was not found for the portals with fixed feet. From the observed horizontal deflections for a case in which the ratio of horizontal to vertical load was 2, a load appreciably above the calculated collapse load of 11·50 tons was supported. The reason for this is the onset of strain hardening as the plastic hinges are developed at the feet of the stanchions, so preventing the catastrophic deflection found in the pin-based frame. This state of affairs has been confirmed in many tests on more complex structures. The effect of strain hardening can be taken into account in the calculation of collapse load, but for design purposes the simple plastic theory has so far proved quite satisfactory enough since it gives a good indication of the stage beyond which the structure develops large permanent deformations.

The results of these experiments on welded structures demonstrate, among many other things, that the residual stress systems set up by welding, which can be such an anxiety in the elastic range, have no effect on the ultimate strength of a structure. Residual stresses form a self-equilibrating system and so if they increase the total stress and hasten yield in some parts of a member they must equally decrease the total stress and delay yield in other parts. The ultimate resistance of the member will thus be unchanged, a conclusion which is to be expected if the problem is regarded from the point of view of strain energy.

Conditions of elastic and plastic instability are being studied intensively but it is not yet possible to give simple comprehensive rules for the use of the designer. There are clear indications, however, that these rules will not be particularly irksome. If you are prepared to accept this assurance you will see what a dependable tool is the plastic theory. It gives the designer an accurate measure of the ultimate strength of a structure; gone are the distressing uncertainties of elastic calculations, which are vitiated by slight sinking of supports, flexibility at connections, residual stresses and all those imperfections which must be present in a real structure.

The only purpose of this lecture has been to draw attention to this advantage but had it not already lasted too long it would be possible to continue and show that a consideration of plastic behaviour makes the direct design of redundant static structures not only a possibility for the first time but a matter of relative simplicity.

SNOWY MOUNTAINS DEVELOPMENT SCHEME.—According to a recent report from Reuter, the Snowy Mountains Hydro-Electric Authority intends to move the site of the proposed Adaminaby dam on the Eucumbene River 5 miles further downstream. This change, it is stated, would treble the storage capacity of the reservoir, bringing it to about 3 million acre-feet and allowing an increase of generating capacity of some 330MW. A detailed account of the Snowy Mountains proposals was given in our issue of June 10, 1949.

The St. Lawrence Project

By Our American Correspondent

A SUBJECT commanding great interest in both political and engineering circles in America at present is the St. Lawrence Seaway and Power Project. The construction of a power plant and of a deep channel through the St. Lawrence River from the Great Lakes to the Atlantic Ocean has been before Congress and the American nation since 1897. So far Congress has taken no action, but Prime Minister St. Laurent of Canada has informed President Truman that his country may decide to build the Seaway alone. Indeed an agreement was announced earlier this week, between the Canadian Government and the Provincial Government of Ottawa, to develop hydro-electric power in the International Rapids of the St. Lawrence River as part of the Seaway Scheme.

The President is said to have endorsed the plan as "the second best," pointing out, however, that he is still in favour of joint construction of the project. In Washington to-day one finds a pronounced apathy towards the St. Lawrence project, which is in striking contrast to the vigorous support it attracted during the Roosevelt administration. There seems to be little American objection to a wholly Canadian approach to the construction of the Seaway, although such unilateral action might be considered to constitute a violation of the Canadian-American boundary waters treaty of 1909, which states that neither party may make any "uses or obstructions or diversions, whether temporary or permanent, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line," unless approved by the International Joint Commission.

There have been good reasons for the apparent Congressional procrastination. As yet no one knows even approximately how much the Seaway and the hydro-electric plant together will cost. The latest low estimate of 1,500,000,000 dollars is hardly more than a guess. Nor does anyone know how much tonnage will pass through the Seaway in ten years. Estimates vary from 25,000,000 to 52,000,000 tons annually. Toll charges and tonnage go together; hence tolls are as much of an enigma as traffic. If both are inadequate, the Seaway may never be self-liquidating. There is no agreement on the depth of the channel. Many organisations are content with 27ft, but others, such as the representatives of shipowners, advocate a 35ft channel. Even the U.S. Army Corps of Engineers cannot agree on the value of the Seaway in times of national emergency, chiefly because the entire Great Lakes region is now a potential target for long-range enemy aircraft flying over the Polar route.

Most engineers maintain that the St. Lawrence project is well worth carrying out. The Seaway would facilitate the tremendous agricultural, mineral and industrial products of the Middle West to be shipped all over the world at low cargo rates. Important inland cities, like Chicago, Milwaukee, Detroit, Cleveland and Buffalo, would become virtual ocean ports. And the additional hydro-electric capacity to be obtained from the project should go far to relieve the present power shortages in Ontario and in upper New York State. It must, however, be realised that, like the United Kingdom, the United States and Canada to-day face a shortage of labour and materials which might become more serious during the five to seven years that it is estimated construction of the project would take. In his recent budget message, Mr. Truman asked Congress for an initial 20,000,000 dollars to launch the St. Lawrence project, and it is to be hoped that this venture, which Mr. Herbert Hoover once called "the greatest internal improvement yet undertaken on the North American continent," will come to be carried out in the near future.

American Engineering News

(By our American Correspondent)

Bridge Contest of the American Institute of Steel Construction

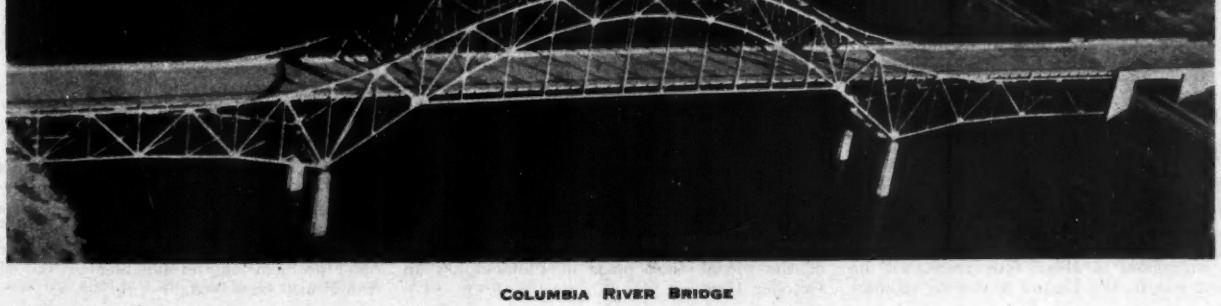
Stainless steel plaques for three bridges selected as the most beautiful steel bridges opened to traffic in the United States last year were awarded recently by the American Institute of Steel Construction. The winners in the contest, which has been conducted annually by the Institute since 1928, were selected by a jury of architects and engineers from ninety-seven entries, more than double the number of entries in 1949. In Class 1, bridges with spans of 400ft or more, the winner was the Columbia River bridge, at Wenatchee, Washington, which is shown in the accompanying engraving. It is owned by the State of Washington Department of Highways, and was designed by George Stevens, bridge engineer of the State of Washington Department of Highways, and was fabricated by the American Bridge Company. In Class 2, bridges with spans of less than 400ft and costing more than 500,000 dollars, the winner was the South Holston River bridge on Tennessee State Highway 34, in Sullivan County, Tennessee. It is owned by the State of Tennessee, was designed by the Tennessee Valley Authority and was fabricated by the Virginia Bridge Company. In Class 3, bridges with spans shorter than 400ft and costing less than 500,000 dollars, the winner was the Caldwell Avenue bridge over the Edens Expressway, in Cook County, Illinois. The owner is Cook County. It was designed by the Cook County Highway Department and the Bethlehem Steel Company was the fabricator.

Performance of Germanium Diodes in an Automatic Computer

The production of germanium diodes for wireless and electronic applications in the United States is believed to have expanded to about 4,000,000 a year. Yet because they are relatively new, few significant data on the characteristics of these valves in extended use have become available. Because it uses some 16,000 germanium diodes for computing and switching functions, with the requirement of very high reliability, the National Bureau of Standards Eastern Automatic Computer (S.E.A.C.) is a particularly suitable proving ground for the diodes, and a recent preliminary study of experience with germanium diodes in the S.E.A.C. programme is, therefore, of interest. The study is based on data compiled during the first six months of operation of the electronic computer after its dedication in June, 1950. Reliability is the outstanding requirement of diodes in computer use and even momentary failure of a single diode will cause maloperation of the computer. In view of this severe requirement, experience with germanium diodes in the S.E.A.C. programme has been considered satisfactory. After 2500 hours under voltage, only about 5 per cent of the diodes initially in service had had to be replaced. The great majority of these replacements were made in the course of routine maintenance checks before the questionable diodes could cause computer maloperation. It is also encouraging that the rejection rate for the several thousand diodes purchased in the last six months of 1950 was less than 2 per cent. The S.E.A.C. computer circuits were designed to use diodes of a single specification, the 50V (back) 50mA (forward) type, such as Sylvania IN34 and IN34A, Kemtron IN34, Raytheon CK705, and General Electric IN48 and IN69. A design value of —40V was selected as being the absolute limit of back voltage that would be encountered and 20mA was chosen arbitrarily as the peak forward current.

Each diode is tested individually before use in the computer. Tests are made twice before a diode goes into service; once before and once after soldering into position. Equally important to reliable computer function are the preventive maintenance checks made at regular intervals on diodes already in service. The diodes are tested for back current at —40V and forward voltage drop at 20mA forward current. For a "normal" diode, i.e., one that does not "creep" appreciably, the permissible back current at —40V is specified as 250 microamperes before soldering, 300 microamperes after soldering and 500 microamperes for units in service. For a "good creeper," corresponding rejection limits are 120, 200 and 300 microamperes. (A "good creeper" is defined as one which drifts less than 50 microamperes and stabilises markedly in the half-minute observation period). The maximum permissible forward voltage at 20mA is 2·0V before or after soldering and 2·3V for units in service.

The deterioration of back characteristics has been the chief reason for the replacement of diodes; and excessive creep has been a



COLUMBIA RIVER BRIDGE

much more frequent reason for replacement than excessive back current. Creep in back current was observed in a substantial percentage of the commercially available diodes tested for computer use, including both the wax-imbedded and the hermetically-sealed designs. The incidence of creep varied between makes, however, as well as from batch to batch. Forward characteristics, unlike back characteristics, deteriorated very little and the number of complete failures, such as short and open circuits, was negligible. It now seems clear that diode creep is not caused to any appreciable extent by imperfect mechanical contact. Although moisture is suspected of playing a certain part, it appears unlikely that some of the creep phenomena, which have been observed, could be caused by moisture alone. Peculiarities in the germanium structure in the neighbourhood of the contact, with sensitivity to small temperatures or to electric fields, would seem to be another possibility. Further work on the heat treatment of the germanium ingots and on the forming of the diodes, may help to explain and solve the creep problem.

In addition to the observations on diodes in regular service, several experiments were also conducted. To study the effect of operating temperature on creep, twenty-nine "creepers" were tested at 25 deg. Cent. and 75 deg. Cent. Although individual units differed, these experiments indicate that drift is not notably aggravated by an increase in temperature within the usual operating range. Another group of eighteen "creepers" was observed for 210 hours at room temperature in an effort to determine whether an observation of one minute or less is sufficient to exclude long-term "creepers." These limited data indicate that one-minute or one-half-minute observations, kept to a 300 microampere limit, satisfactorily exclude those units which would later drift beyond 500 microamperes. Pursuing the theory that creep might be related to moisture contamination, some experiments were conducted in which several makes of diodes were subjected to water soaking at room temperature. The chief effect of soaking on non-hermetically-sealed units was to raise the back current and produce "jumping"; the back current at —40V would rise to at least 1000 microamperes and frequently to 2500 microamperes and would swing in an erratic fashion back and forth over a range of several hundred microamperes, the swing taking from one to five seconds. Furthermore, experimental attempts were made to salvage some of the water-soaked diodes, either by baking or with heavy forming currents similar to those used in the original manufacture. Both treatments proved distinctly beneficial. When the heavy-current salvage treatment was tried on "creepers" rejected for use in the computer, great improvement was noted in about one-third of the rather small number treated, while the other two-thirds deteriorated. Limited though these soaking and salvage data are, they point to the possibilities of both the salvage of rejected diodes and the manufacture of more stable diodes by increased pulse-forming treatment and perhaps by baking.

Utilisation of Low-Grade Iron Ores

After many years of experiment the American steel industry is now commencing the practical utilisation of low grades of domestic iron ore, known as taconite. The Reserve Mining Company of Cleveland, Ohio, which is owned by the Republic Steel Corporation, the Armco Steel Corporation and the National Steel Corporation, has awarded construction contracts for an ore beneficiation plant at Beaver Bay, Minnesota. Contracts having a total value of 75,000,000 dollars have been given jointly to three companies—the Runkin-Conkey Construction Company of Cleveland, the Arundel Corporation of Baltimore, Md., and the L. E. Dixon Company of San Gabriel, California. The plant, which is to be completed in about four years, will be the first one in the United States to produce blast furnace feed in commercial tonnages from taconite ore. It has been designed to produce about 2,500,000 tons of high-grade ore from 7,500,000 tons of taconite annually. The taconite will be pulverised to a powder as fine as cement and the iron mineral will be separated from the sandy waste material by a magnetic process. The iron mineral then will be rolled into walnut-size pellets and baked in a furnace before delivery to the steel mills. The Reserve Mining Company claims that by its process taconite with an iron content of about 25 per cent will yield iron ore pellets containing about 64 per cent iron at a cost competitive with other Lake Superior ores. A 47-mile-long railway to the ore pits at Babbitt, Minnesota, and a complete ore-loading harbour, with breakwaters, are part of the Beaver Bay project. Two other projects, designed to develop a commercially feasible method of extracting the iron content from taconite are still in the pilot stage but one of them, the plant of the Erie Mining Company at Aurora, Minnesota, has progressed to the stage where it will soon be in operation on a production, rather than an experimental, basis.

Completion of Grand Coulee Power Plant

THE largest hydro-electric power plant in the world was completed when the eighteenth and last generator went on the line at Grand Coulee Dam, in central Washington, on September 14th, giving the plant a 1974MW generating capacity. The new generator will produce 108MW. But, large as the plant is, there is already discussion of the possibility of further expansion by adding a third group of generators to help meet the rising power requirements of the Pacific North-West of the United States. Because of the large power demand the generators are frequently and safely run at capacities 20 per cent greater than their rated 108MW per unit. It is claimed that a world's record for hourly production of hydro-electric energy at one plant was recently set in excess of 2,000,000kWh for the first time in history. The following are the records for hourly, daily, weekly, monthly and yearly energy production held by Grand Coulee:—

Hourly—2,123,000kWh, August 14, 1951.
Daily—47,279,000kWh, January 29, 1951.
Weekly—323,489,000kWh, March 4–11, 1951.
Monthly—1,191,895,000kWh, January, 1951.
Yearly—11,419,000,000kWh, calendar year of 1950.

American Diesel-Electric Locomotive for Australia

The first General Motors diesel-electric locomotive built outside the North American continent went into service in Australia recently. Officials of General Motors and its electro-motive division participated in ceremonies at Port Pirie, South Australia, marking the opening of new, speedier transcontinental passenger service in Australia, due to the use of the new locomotive. The engine is a special export model and was built by the Clyde Engineering Company, of Clyde, New South Wales, the Australian affiliated company of the electro-motive division. Its power plant, transmission equipment and controls were supplied from the United States. The new locomotive will serve a train of the Commonwealth Railways on the Australian Transcontinental Railway from Port Augusta to Kalgoorlie, and is expected to cut twenty hours off the previous three-day schedule for the 1051-mile run.

The Franklin Medal

The Franklin Institute, of Philadelphia, has announced the award of its highest honour, the Franklin Medal, to Sir James Chadwick. Since 1914 the medal has been awarded annually to a worker in physical science or technology whose work did "the most to advance a knowledge of physical science or its application." The presentation of the medal took place in Philadelphia on October 17th.

French Engineering News

(From our French Correspondent)

Monsieur Robert Defraiteur, of the Aciéries du Nord, recently explained how the nationalisation of the railways had affected the locomotive manufacturing industries in France. He pointed out that 80 per cent of the industries' orders were for the S.N.C.F., which comes under the Government and whose spending can be stopped instantly. In 1919, Monsieur Defraiteur said, the French railways ordered 1235 locomotives. Now, since the Liberation six years ago, the nine firms capable of building an average of from 600 to 700 locomotives a year between them, had been asked to build 873 locomotives only, or 140 per year. He admitted that there were special reasons for this. In the first place the electrification of many important lines released locomotives for employment on other lines. Secondly, many secondary lines were now served by autorail cars only and many small lines had been closed altogether. The 20 per cent of orders coming from private firms which used steam locomotives showed a serious falling off in quantity because many of these firms were now using diesel locomotives.

The one hope since 1946, continued Monsieur Defraiteur, had been foreign markets. Important orders had come in from India, Egypt, Brazil, Australia, &c., and locomotives were now being delivered to those countries. But the orders were not being renewed. French prices were too high and the growth of competition from both Germany and Japan had made the French position difficult. Three of the nine manufacturers had therefore started making mechanical parts for electric and diesel-electric locomotives. They were capable of equipping about 250 locomotives per year and had received some important orders from both Holland and Spain.

The twenty-six firms producing tenders, trucks and autorail cars had a capacity of about 18,000 vehicles per year at normal production, although since the Liberation the rate of construction had been no more than 5460. The manufacturers were therefore asking for a long-term programme of construction so that they might organise accordingly. The S.N.C.F., however, owing to its financial position, found itself unable to meet this request, and the industry was therefore looking to foreign markets.

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Work on the construction of the first section of the Paris-Lille motorway is about to start in the Nord Department. The new motorway, which will be one of the most important in France, will link the capital and the industrial zone of Flanders, which is at present very inadequately served by road. Two highways are envisaged for the departure from Paris itself, one to the North and the other to the East.

* * *

A bill has been introduced into the National Assembly to modernise the North-East Canal between the Belgian frontier and Sedan, and to study the possibility of a canal connecting the Lorraine basin and the Rhine to the Nord basin. For economic reasons, it is pointed out, a direct link between the North Sea and the Lorraine basin is needed. A possible route already exists, but whereas 1700-ton vessels can travel as far as Liége, and 450-ton vessels up to Givet, French locks will only permit 340-ton barges to pass. Belgium envisages the broadening of the Liége-Givet section to increase navigational possibilities. The plan suggested for France includes increasing the permissible draught, the construction of large locks, while decreasing the number of locks, so that 1700-ton vessels may pass, and modern barrages. The work envisaged, which would cost about 7 milliard francs, would include the reconstruction of bridges destroyed on the Meuse. At the same time such modernisation would enable Electricité de France to carry out the programme elaborated for the electrification of the Meuse and Semoy by the construction of hydro-electric plants. The important problem of the flooding of the Meuse would also be solved.

Industrial and Labour Notes

The Steel Problem

The latest issue of *Bulletin for Industry*, which is a review of the economic situation prepared by the Treasury, says that it is going to be very difficult to get more production out of the metal-using industries unless more steel goes into them! There is now no chance of producing as much steel this year as last year, and the outlook for next year's production is not much brighter. There is no likelihood of being able to import further large quantities of scrap from Germany, so that the prospects for steel production depend mainly on the import of rich iron ore.

That, the *Bulletin* points out, depends largely on our exporting coal in exchange. But on the most cheerful estimate of coal and iron ore supply, the steel shortage seems likely to remain; hence, the importance to this country of its recent request to the U.S.A. for imports of steel. If the metal-using industries here could be supplied with sufficient material, they could obviously get much nearer to being able to provide enough equipment for rearmament, home investment and exports as well. On the subject of steel from the U.S.A., the Minister of Supply said in Parliament on Monday last that, so far, the United Kingdom had been authorised to place orders for 93,000 tons of ingots, and had been allocated 25,000 tons of finished steel for the first quarter of 1952. That quantity would be debited against the total tonnage of steel for which the United Kingdom had asked in 1952. The Minister added that negotiations with the U.S.A. were continuing.

Railway Freight Charges

In reply to a question in Parliament last week, the Minister of Transport, Mr. Maclay, stated that the British Transport Commission had drawn his attention to the actual and prospective rises in its costs through increases in wage rates and prices. The Commission had applied for authority, under Section 82 of the Transport Act, to increase existing railway freight charges by 10 per cent subject generally to a maximum of 10s. per ton. The Commission's proposals would increase charges for small parcels by goods train by about 20 per cent, charges for the carriage of returned empties by 50 per cent, and dock and canal charges by 10 per cent. The Minister said that he had asked for the advice of the permanent members of the Transport Tribunal, acting as a consultative committee.

The Coal Situation

The *Bulletin for Industry*, referred to in a preceding note, has stated that "if we had 20,000,000 tons more coal, we could earn some £70,000,000 if we exported it all." That, of course, would be a useful contribution to offset the deficit with the European Payments Union. But, as it is, the Treasury estimates that, judging by the first nine months, coal will earn this year about £24,000,000 less than in 1950. Imports of American coal have already cost this country about 24,000,000 dollars this year, or more than £7 a ton including freight, and, it is added, "this winter each ton may well cost more."

The *Bulletin* also discusses the chances of getting another 20,000,000 tons of coal a year, pointing out that production depends on the number of miners, the efficiency of management, the equipment of the mines, and the morale of the miners as reflected in the number of shifts worked and their output at the face. It is agreed, of course, that improved equipment at the coal face should continue to push up productivity and, with it, total production, but, nevertheless, the need is for more coal now, and that is dependent upon an increase in mining manpower and upon higher output per head.

Since last April, the mining labour force has declined by about 9000, although in the past three or four weeks the numbers have remained steady. The particular need is for more young miners. In the 1920s about 45 per cent of all employed coal miners were under thirty-one, compared with 30 per cent to-day; the average age is now steadily rising, and last year it was over forty. The industry is, therefore, depending on older miners inherited from the early 1920s when it employed 1,200,000 men compared with the present total of something under 700,000.

Total coal production so far this year is just over 5,000,000 tons more than it was last year, but inland consumption has been nearly 7,000,000 tons higher. On November 17th, distributed stocks of coal amounted to 17,099,000 tons, compared with 15,260,000 tons on the corresponding date last year.

Coal Miners' Wages

Last week it was stated that the executive of the National Union of Mineworkers had met representatives of the National Coal Board for a discussion of a claim for wage increases. According to reports, the Coal Board has offered to increase the minimum rates of underground workers by 13s. 6d. a week to £7 0s. 6d., and of surface workers by 11s. 6d. to £6 1s. 6d. The proposal for pieceworkers is that they should receive an increase of 2s. 3d. a shift. The union's original claim was that the wages of underground workers should be increased by £1 3s. a week and those of surface workers by £1 a week, and that pieceworkers should receive an extra 3s. a shift.

The union executive has decided to recommend that the Coal Board's offer should be accepted by a delegate conference which has been summoned for to-day, Friday. There has also been discussion of a suggestion made by the Coal Board that miners should accept a week's pay in place of an extra week's holiday next year. The Board has also stressed the need for a uniform system of piecework payment, a matter in which the union has agreed to co-operate. If the wage proposals which have been made are put into operation, it is estimated that they will add about £18,000,000 a year to the Coal Board's wages bill.

Films for Industry

The Federation of British Industries has just published a useful booklet giving practical guidance on the sponsoring and distribution of industrial films. It has been compiled under the direction of the F.B.I. home publicity committee, which advances the view that people in this country and overseas should have greater opportunity for learning about British industry's achievements and methods, and that the film is an excellent means of making the facts known. After outlining the questions which a film sponsor ought to ask before deciding upon the making of a film, the booklet describes the various kinds of film that can be made on industry's behalf. Such films, it is suggested, are likely to come under the following heads: public relations, sales promotion, staff education and information, and staff training. The booklet deals with such essential points as the preparation of the film "brief" and copyright and with the factors affecting the cost of films and film strips. There is also information on the channels and services by which industrial films are distributed to such places as schools, clubs, institutes, and works canteens.

The booklet costs 1s. 8d. Copies of it can be obtained from the Federation of British Industries, 21, Tothill Street, London, S.W.1.

The Industrial Welfare Society

The twenty-fourth annual general meeting of the Industrial Welfare Society was held in London on Wednesday afternoon. The report of the council, covering the year ended June 30th last, which was presented at the meeting, emphasises that the Society's resources have been increasingly occupied with problems concerning human relations, leadership and joint consultation in industry. The Society's membership continues to increase, and in the year reviewed the residential conferences organised by the Society were attended by no less than 2250 delegates from over 500 different companies, compared with 1310 delegates in the preceding year. An important development last year was the starting of conferences especially for apprentices and trainees in industry.

Moving the adoption of the report, Mr. H. H. Bagnall, chairman of the council, made special mention of the work of Sir Robert Hyde, the Society's founder, who, he said, was retiring from the staff at the end of this year. In the early days of the Society, Mr. Bagnall commented, Sir Robert was one of the pioneers of the movement for promoting the welfare of those engaged in industry. That movement had now developed into the accepted part of our national life and was recognised as being of paramount importance to industry and the country generally.

Mr. Bagnall went on to say that the Society's member firms employed over 7,000,000 people and that the Society's future was dependent upon the quality of the service which it could render to industry and those engaged in it. To perform that service efficiently, he claimed, the Society must keep abreast of all the many and varied developments which affected people at work, and must itself seek for new means of improving industrial welfare in the widest sense of that term.

Index of Industrial Production

The index number of industrial production (1946=100), which is prepared by the Central Statistical Office, has been estimated provisionally at 145 for September, compared with 127 for August. Figures for the corresponding months last year were 143 for September and 123 for August. It must be remembered, of course, that the figures for August each year are affected by annual holidays. Taking the manufacturing industries alone, the September index number this year has been estimated as 151, compared with 132 for August. It is stated that, on the basis of information so far received, the index for all industries in October is likely to be 151 or 152.

The Elderly Worker

The Industrial Welfare Society has published this week a pamphlet which is intended as a guide to employers in considering the need to employ elderly workers. The information contained in it is based mainly on the results of an investigation into the matter which the Society carried out among some 400 of its member firms last year.

The survey showed that the proportion of male elderly workers (age sixty-five and over), as against all workers, employed by individual firms had dropped from 4·3 per cent in 1945 to 2·7 per cent in 1950, although for women it had increased slightly. The conclusion reached, therefore, is that, whilst it is not known how many elderly workers may be available to industry now and in the future, this potential source of labour is not at present being used as effectively as it might be.

The problems concerned with the employment of the elderly are discussed briefly in the pamphlet, and there are also some notes on training, the earnings and output of elderly workers, and the influence of the elderly upon other employees. The pamphlet says on this latter point that many firms have commented on the stabilising influence that elderly workers have on their labour forces. In many cases they have in fact been used specifically in the training of new labour with the idea of relieving the foreman.

Notes and Memoranda

Rail and Road

MOTOR EXHIBITIONS IN 1952.—The Society of Motor Manufacturers and Traders has announced that the council of the Society has decided that both the Motor Show and the Commercial Motor Show shall be held next year at Earls Court. The Commercial Motor Show is planned for September 26 to October 4, 1952, to be followed by the Motor Show from October 22 to November 1, 1952. With a view to promoting sales in Canada, the Society has also arranged for British manufacturers to show their products in a special British section within the Canadian National Exhibition to be held at Toronto in August/September next year.

ROAD PASSENGER TRANSPORT SERVICES.—A summary of the annual reports of the licensing authorities for public service vehicles for the traffic areas in Great Britain, covering the period April 1, 1950, to March 31, 1951, has now been published by H.M. Stationery Office. The reports by the licensing authorities have been presented, for economy's sake, in the form of summaries, extracts and statistical tables, and give an account of the year's work in licensing road passenger services, public service vehicles, and the drivers and conductors of these vehicles, and in carrying out other duties laid on the licensing authorities by the Road Traffic Acts, 1930–47. Details of the numbers of operators and of public service vehicles are also given.

COURSES IN HIGHWAY AND TRAFFIC ENGINEERING.—The British Road Federation, 4a, Bloomsbury Square, London, W.C.1, recently conducted a survey to determine the courses in highway and traffic engineering which were available at universities and colleges throughout the country. Twenty-eight universities or colleges were approached and it was found that specialised courses and/or research on subjects relevant to highway engineering were available in ten instances. Highway engineering itself was covered in one case only, as a post-graduate course. Traffic engineering to a greater or lesser degree was dealt with by two universities. The remainder offer courses in civil engineering with no form of specialisation in the subjects in question.

Miscellanea

FUEL AND POWER ADVISORY COUNCIL.—The Minister of Fuel and Power has announced the appointment of Sir Ewart Smith and Captain (E.) William Gregson, R.N.R., to the Scientific Advisory Council, which was set up in 1948 to advise the Minister on the scientific aspect of his statutory duties. Sir Harry Ricardo, F.R.S., and Engineer Vice-Admiral Sir Harold Brown have retired from the council.

DIESEL-ELECTRIC GENERATING STATION AT DALIBURGH.—A scheme prepared by the North of Scotland Hydro-Electric Board, for building a diesel-electric generating station at Daliburgh, in the island of South Uist, has been confirmed by the Secretary of State for Scotland. Particulars of the scheme (which is estimated to cost £52,000) are given in a White Paper published by H.M. Stationery Office, 13A, Castle Street, Edinburgh.

AUTOMATIC DOOR-SWITCH.—We have received brief particulars of a small switch designed for operation in conjunction with doors of refrigerators, &c. A product of Arcolectric (Switches), Ltd., West Molesey, Surrey, it is rated at 1A, 250V, and is designed for fixing in a single ¼in hole, the overall dimensions of the switch being approximately ¾in wide by 1¼in long, with the plunger extended. It is biased normally "on"; a small depression of the plunger breaks the circuit and the rest of the movement is overrun. The slow make and break is intended to ensure long life. All current-carrying parts are heavily silver-plated. The plunger and the case shielding the contact mechanism are of black moulded plastic construction.

A CATALOGUE LIBRARY.—The Engineering Centre, 351, Sauchiehall Street, Glasgow, C.2, has now opened a catalogue library which contains the literature of more than 3000 firms and also a complete set of British standards. Frequent additions by the firms concerned, and constant supervision by the Centre's technical staff, ensure that the library contains only the most recent publications. The facilities offered by this source of information are already being put to good use by consultants, designers, draughtsmen and buyers, as well as by the many overseas visitors who now include a visit to the Centre in their itineraries. Manufacturers who have not included the Centre's name on their mailing lists for publicity matter are invited to do so.

THE BRITISH ASSOCIATION.—Next year's meeting of the British Association for the Advancement of Science is to be held at Belfast from September 3rd to 10th. Professor A. V. Hill, C.H., F.R.S., has been elected president of the Association, Mr. M. G. Bennett, general treasurer, and Sir Richard Southwell, F.R.S., and Dr. George Taylor, general secretaries. Sir Ben Lockspeiser, F.R.S., has been elected president of Section G, Engineering, and Professor A. M. Tyndall, F.R.S., has been elected president of Section A, Mathematics and Physics.

POWER STATION EXTENSIONS AT DEPTFORD EAST AND LITTLEBROOK "C."—The British Electricity Authority has received the consent of the Ministry of Fuel and Power to extensions of the Deptford East and Littlebrook "C" (Dartford) power stations. The extension of the Deptford East power station will consist of one 52·5MW turbo-alternator and two boiler units, each of an evaporative capacity of 250,000 lb of steam per hour, and the extension at Littlebrook "C" of one 60MW turbo-alternator and two boiler units, each of an evaporative capacity of 360,000 lb of steam per hour.

COATED PAPERS FOR RUST PREVENTION.—A booklet has been published by Leonard Stace, Ltd., of Cheltenham, describing the properties and uses of its "V.P.I." papers for the protective packing of metal articles. The "V.P.I." (or vapour phase inhibitor) paper is unusual, in that it prevents corrosion of metal articles when moisture and oxygen are present. With it a tightly sealed package is not necessary, as the slightly volatile chemical in the paper vaporises slowly to form a non-corrosive local atmosphere. In this way condensed water on a metal surface in a package absorbs the "V.P.I." and becomes incapable of causing rust.

Contracts

A CONTRACT for the construction of 104 rapid transit cars for the 4ft 10½in gauge Yonge Street subway has been placed with the Gloucester Railway Carriage and Wagon Company, Ltd., by the Toronto Transportation Commission. This contract is reported to be worth some 7,800,000 dollars. The cars, it is reported, will each be about 57ft long and 10ft wide, and seat sixty-two passengers. In service the cars will be made up into two, four, six or eight-car trains, the cars being semi-permanently coupled in pairs which work as units in off-peak hours. Motor equipment for the new cars will be supplied by Crompton Parkinson, Ltd., and the control equipment by the British Thomson-Houston Company, Ltd.

DURING the past month, the British Electricity Authority has placed contracts for equipment for power stations, transforming stations and transmission lines amounting in the aggregate to £13,149,708. The principal contracts include: East Yelland power station, near Barnstaple, main and auxiliary power cables, control cables and accessories (Aberdare Cables, Ltd.); Portishead "B" power station, near Bristol, foundations of buildings, circulating water system, cable tunnels, coal store and ancillary work (Chas. Brand and Son, Ltd.); Brimsdown power station, near Enfield, two 340k-lb per hour boilers (John Thompson Water Tube Boilers, Ltd.); Castle Donington power station, near Derby, preliminary civil engineering work (Wm. Moss and Sons, Ltd.); Drakelow power station, Burton-on-Trent, main and auxiliary cables and accessories (British Insulated Callender's Cables, Ltd.); Bold power station, St. Helens, two 300k-lb per hour boilers (Yarrow and Co., Ltd.); Connah's Quay power station, near Flint, two 300k-lb per hour boilers and coal handling plant (International Combustion, Ltd.); Ince power station, near Ellesmere Port, foundations and culverts (Holland and Hannen and Cubitts, Ltd.); Clarence Dock power station, Liverpool, three 350k-lb per hour boilers (Babcock and Wilcox, Ltd.); Doncaster power station, four 180k-lb per hour boilers (Mitchell Engineering, Ltd.); Skelton Grange power station, Leeds, 132kV, 2500MVA switchgear (British Thomson-Houston Company, Ltd.); Huddersfield power station, two 180k-lb per hour boilers (Bennis Combustion, Ltd.); Stella South power station, near Newcastle upon Tyne, main foundations, &c. (Sir Robert McAlpine and Sons (Newcastle upon Tyne), Ltd.), and 132kV overhead line (W. T. Henley's Telegraph Works Company, Ltd.); Chadderton power station, Oldham, two 360k-lb per hour boilers (Simon-Carves, Ltd.); Brasehead power station, Renfrew, one 300k-lb per hour boiler (Babcock and Wilcox, Ltd.); Slough, two 120MVA, 275/132kV auto-transformers (General Electric Company, Ltd.).

Personal and Business

SIR DAVID BRUNT, F.R.S., has been appointed a director of the Fulmer Research Institute, Stoke Poges, Bucks.

MR. C. F. MONTGOMERY has been appointed general works manager at the Weybridge factory of Remington Rand, Ltd.

MR. C. ST. VINCENT SMITH, M.I.Mech.E., has been appointed a director of Richard Garrett Engineering Works, Ltd., Leiston, Suffolk.

PHILIP AND SON, Ltd., Dartmouth, announces that Mr. W. S. Bates, who is the secretary of the company, has been appointed a director.

MR. M. H. L. LEWIS, M.A., has been co-opted to the board of executive directors of Crompton Parkinson, Ltd., for a period of six months.

ALFRED HERBERT, Ltd., Coventry, states that it has acquired a controlling interest in the Sigma Instrument Company, Ltd., Letchworth, Herts.

FINA PETROLEUM PRODUCTS, Ltd., states that its head office has been moved to 25, Victoria Street (South Block), London, S.W.1 (telephone, Abbey 7822).

MR. DONALD F. ANDERSON, deputy chairman of the Peninsular and Oriental Steam Navigation Company, has been appointed chairman of the owners' side of the National Maritime Board.

MR. M. W. SHORTER, director and general sales manager of Westinghouse Brake and Signal Company, Ltd., has been appointed to the board of W. R. Sykes Interlocking Signal Company, Ltd.

GLOVER AND MAIN, Ltd., announces the formation and registration of a new subsidiary entitled Main Refrigeration, Ltd., for the production of domestic refrigerators. The directors are Mr. P. D. M. Aird, Mr. F. Dunn, and Mr. C. Marley.

MR. L. H. LEEDHAM, M.I.Mech.E., superintendent of works and general services at the National Gas Turbine Establishment, has been appointed Assistant Director of Aircraft Production Development, Ministry of Supply.

THE FAIREY AVIATION COMPANY, Ltd., announces that the name of its Australian subsidiary has been changed to Fairey Aviation Company of Australasia Pty., Ltd. The company's postal address at Box 41, P.O. Bankstown, N.S.W., is unchanged.

BRITISH RAILWAYS announce the following appointments in the Western Region:—Mr. E. C. Cookson, A.C.G.I., M.I.C.E., assistant civil engineer; Mr. F. E. Pheasey, assistant to the commercial superintendent (passenger and parcels).

THE BRUSH ELECTRICAL ENGINEERING COMPANY, Ltd., states that Earl De La Warr has resigned from the board on appointment as Postmaster-General. Mr. Ian T. Morrow has been appointed a director, and will act as financial controller of the Brush A.B.O.E. group.

HEAD WRIGHTSON AND CO., Ltd., states that Mr. John Long, assistant manager of its London office, has been appointed London manager in succession to Mr. Selby Robson. Mr. Robson remains a director of the company and of Head Wrightson Processes, Ltd.

KEITH BLACKMAN, Ltd., Mill Mead Road, Tottenham, N.17, announces the retirement of its chief London representative, Mr. J. C. Campbell, after fifty years' service. He is succeeded by Mr. D. J. Auld, who joined the company in 1914 and has been a representative for the past twenty-seven years.

THE SHELL PETROLEUM COMPANY, Ltd., announces that Mr. James Grant has been appointed manager of the Shell Haven (Essex) refinery in succession to Mr. R. W. J. Smith. It states also that Mr. J. L. Flanagan, manager of the fuel oil general department, will retire at the end of the year and will be succeeded by Mr. D. B. Vale.

Launches and Trial Trips

ALCINOUS, cargo and passenger liner; built by Vickers-Armstrongs, Ltd., for Alfred Holt and Co., for the China Mutual Steam Navigation Company, Ltd.; length overall 487ft, breadth moulded 62ft, depth moulded 35ft 3in, deadweight 9000 tons; Kincaid-Burmeister and Wain diesel engine, seven cylinders, 7000/7600 b.h.p., service speed 15½ knots. Launch, November 27th.

CLUTHA RIVER, motor tanker; built by R. and W. Hawthorn, Leslie and Co., Ltd., for the British Empire Steam Navigation Company, Ltd.; length overall 557ft, breadth moulded 70ft, depth moulded 39ft 6in, deadweight 18,000 tons; Hawthorn-Doxford oil engine, six cylinders, 725mm diameter by 2250mm combined stroke, 7600 b.h.p. at 114 r.p.m. Launch, November 29th.

British Patent Specifications

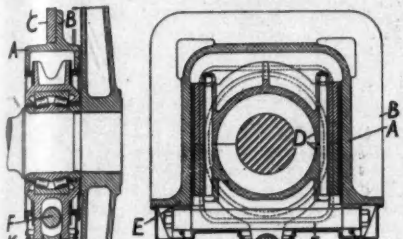
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

RAILWAY ENGINEERING

660,237. February 24, 1949.—Axle Bearings of Railway Vehicles, The English Electric Company, Ltd., Queens House, 28, Kingsway, London, W.C.2 (*Inventor: John Oliver Philip Hughes*).

The invention is mainly concerned with the horn-stays which bridge the cut-outs provided in the main frame for the assembly of the horn-guides and axle-boxes. According to the invention the horn-stay is formed by a threaded bolt screwed in the longitudinal direction of the vehicle frame into two downward extensions of the horn-block beyond the range at which it serves as a guide to the axle-box. In the drawing, the horn-block guide *A* is attached by its flange *B* to the locomotive main frame *C*. The axle-box *D*, consisting of an upper and lower half, is guided in this horn-block guide and contains a self-aligning double



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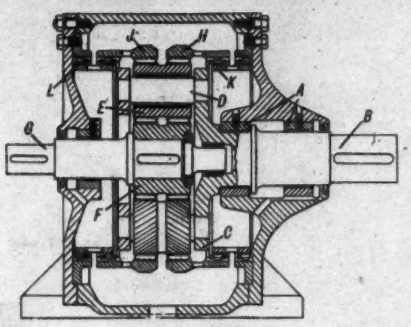
roller bearing. The vertical arms of the horn-block guide are extended downward at *E* beyond the guiding surfaces and both these extensions are tapped by a screw thread which is virtually a single continuous thread. A bolt *F* forming the horn-stay is screwed through both extensions. The extensions *E* are vertically split downwards and pinch bolts *G* are inserted at right angles to the axis of the stay-bolt to clamp the tapped extensions against the threaded ends of the stay. As shown, a single stay is used which is flanked at both sides by downward arms of the lower half of the axle-box *D* connecting up with the hanger *H* of the main spring *J* by means of a pin *K*. Alternatively, two parallel stay-bolts can be arranged flanking a single downward arm of the axle-box.—*October* 31, 1951.

POWER TRANSMISSION

660,497. June 3, 1949.—Epicyclic Gears with Double Helical Teeth, Wilhelm Gustav Stoeckicht of Rugendasstrasse 4, München-Solln, Germany.

In the gears described working difficulties are obviated by subdividing at least one of the central wheels in such a way that two helically toothed wheels with oppositely directed obliquities of teeth are obtained. These toothed half-wheels are yieldingly connected with one another and with the member that takes up the torque of the central wheel. The yielding connections are constructed to permit small movements of the halves of the central wheel in the plane perpendicular to their axis and also small angular movements. A casing with bearings *A* supports a shaft *B*, which carries the planet-carrier *C* of a sun-and-planet gear. In the planet-carrier are mounted planet pinions *E*, on studs *D* which are provided with double helical teeth. They mesh on the one hand with a sun wheel *F*, mounted fast upon a shaft *G*, with journals in the casing and in the shaft *B*. With one half of their double helical teeth the planet pinions *E*, mesh with an outer central wheel or annulus *H* and with the other half of their double helical teeth they mesh with a second central wheel or annulus *J*. The two central wheels are provided with simple helical teeth, the inclinations of which are oppositely directed. The central wheels are non-rotatably connected with the casing by double-toothed couplings *K* and *L* respectively, which give the central wheels *H* and *J* a degree of freedom for self-adjustment for compensating for errors in pitch, to equalise distribution of load of the tooth-engagement forces. It is advantageous to construct the teeth of the couplings *K* and *L* as helical teeth, the angle of obliquity being so selected that the axial thrusts arising from the tooth pressures of the central wheels are transmitted by way of the teeth of the toothed couplings. The outer central wheels are so constructed that under the action of the radial tooth



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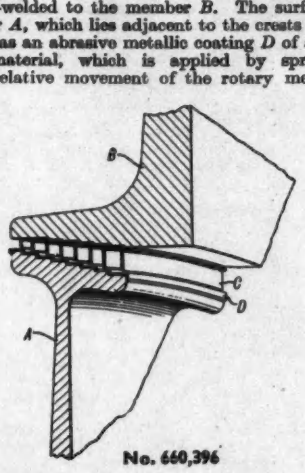
forces each of them can execute small movements in a plane perpendicular to the axis, and also slight angular movements, independently of the other, in such a way that by this means again an equalisation of tooth loading occurs. Two other forms of construction are shown in the specification.—*November* 7, 1951.

GAS AND STEAM TURBINES

660,396. March 23, 1949.—Labyrinth Seals, Burton Albert Avery, 210, William Street, Weston, Ontario, Canada, and Jean Paul Laviolette, of 126, Arundel Avenue, Toronto, of Ontario, and A. V. Roe, Canada, Ltd., of Malton, Ontario, Canada.

As shown in the drawing, sealing action between the relatively rotatable members *A* and *B* is provided by sealing rings *C*, which are made of thin gauge soft material, such as aluminium or brass. These rings are made of "L"-shaped sheet and are lap-welded to the member *B*. The surface of member *A*, which lies adjacent to the crests of the rings, has an abrasive metallic coating *D* of a very hard material, which is applied by spraying. Upon relative movement of the rotary members



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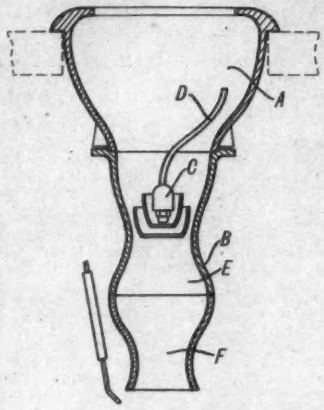
after assembly the abrasive coating begins to grind the comparatively soft material of which the rings are made and this action continues until no further fouling occurs between the rings and their adjacent surfaces. Thereafter, if any distortion experienced in the normal operation of the machine causes contact between the rings and the adjacent relatively moving surface there will be a resumption of the grinding operation. The small particles of metal thus ground are carried away in the stream of vapour or gas flowing through the seal. Eventually a clearance is provided which is sufficient to satisfy all conditions of operation and since this clearance is an absolute minimum the most efficient seal is achieved.—*November* 7, 1951.

STEAM GENERATORS

659,950. June 13, 1949.—Oil-Fired Furnace, Julius William Gudmand-Hoyer, of Dalumvej 9, Fruens Boge, Denmark.

The drawing shows an axial section through an oil burner arranged for suspension from a fire door opening in the top of the furnace. The oil burner comprises an air chamber *A*, to which compressed air is supplied by means of a motor-driven fan. This compressed air chamber is fitted with an air nozzle B with a narrow part into which an oil nozzle *C* with an atomiser is inserted. The oil is supplied through an oil pipe *D*. The oil nozzle is movable in an axial direction in relation to the air nozzle, so that by experiment the position in which the best atomisation of the oil flowing from the oil nozzle may be found. In front of the oil nozzle in the direction of the air current is a wide portion *E* and a narrower portion *F* forming the flame nozzle of the burner. The flame nozzle may be divergent or convergent according to the form desired. After passing the portion *E*, the mixture of oil and air flows through *F* to leave the burner at a high speed, and is ignited just outside the burner. The flame



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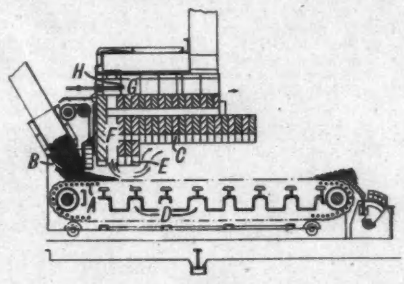
nozzle is so adjusted that the velocity of the mixture through it is greater than the flame velocity, so that the flame will be prevented from firing back.

As shown in the drawing, the compressed air chamber *A* is provided with a flange by means of which it can be made to fit as a lid over the fire door opening in the top of the furnace.—*October* 31, 1951.

659,894. January 10, 1949.—Furnaces of Water-Tube Boilers, The North Thames Gas Board, formerly the Gas Light and Coke Company; and Ambrose Higgins, 30, Kensington Church Street, London, W.8.

This invention relates to furnaces for water-tube boilers employing mechanical stoking and it has for its object to provide an improved arrangement for achieving early ignition of the fuel after its entry into the furnace. In the drawings *A* is a moving grate to the receiving end of which finely divided, solid fuel is delivered by gravity from a chute at a rate determined by the height of a vertically adjustable fire door *B*. A series of adjustable dampers is provided beneath the grate. In order to obtain early ignition of the fuel fed on to the moving grate the ignition arch *E* is formed by a projection from the main firebrick arch *C* and located a short distance ahead of the fire door *B*. This arch extends to within a short distance of the surface of the grate. The practice is to maintain a high temperature zone within the furnace in the region of the ignition arch and the



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part of the main arch adjoining it by keeping the forced draught dampers in the region well open, the entering fuel being ignited mainly by radiation from the ignition arch *E* and that part of the main arch close to it. One or a number of upwardly directed passages *F* are provided through the upper part of the firebox structure between the fire door and the ignition arch. They connect with further forwardly directed passages *G* through the fire-box structure above the main arch. Through them hot gases are blown back beneath the ignition arch over the layer of entering fuel, as indicated by the arrows, to assist the ignition of the fuel. The gases then pass on through other passages to join the main stream of hot gases passing to the water tubes. Steam nozzles *H* discharging into the passages leading to the nostrils create suction beneath the ignition arch. In addition to longer service between resetting of the brickwork, it has been found possible, making use of the construction described, to increase the evaporation figure of some boilers by approximately 30 per cent.—*October* 31, 1951.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Supervising Electrical Engineers

Mon., Dec. 10th.—CENTRAL LONDON BRANCH: St. Ermin's Hotel, Caxton Street, London, S.W.1, "Air Conditioning and its Applications," H. G. Y. Green, 7 p.m.——N.W. LONDON BRANCH: Prince of Wales Hotel, Kingsbury Road, N.W.9, "Variable Speed A.C. and D.C. Motors," L. W. Marshall, 7.45 p.m.

Tues., Dec. 11th.—S.W. LONDON BRANCH: St. George's Hall, St. George's Road, Wimbledon, "Branch Lecturettes," 8.15 p.m.

Wed., Dec. 12th.—COVENTRY BRANCH: Technical College, Coventry, "Earthing," P. W. Cave, 7.15 p.m.——BRADFORD BRANCH: Midland Hotel, Bradford, "The Science of Electronics," R. A. Chelloner, 7.30 p.m.

Fri., Dec. 14th.—BRISTOL BRANCH: Grand Hotel, Bristol, "Lighting—Theory and Practice," R. S. Hazell, 7.30 p.m.——CREWE BRANCH: Copeland Arms Hotel, Glebe Street, Stoke, "Television," R. U. Peters, 7.30 p.m.——NOTTINGHAM BRANCH: Electricity Showrooms, Smithy Row, Nottingham, "Motor Control Gear," P. C. Belton, 7.30 p.m.

Birmingham Association of Mechanical Engineers

To-day, Dec. 7th.—James Watt Memorial Institute, Great Charles Street, Birmingham, "Metallurgical Inspection," E. Wood, 7 p.m.

Engineers' Guild

Wed., Dec. 12th.—16, Queen Anne's Gate, London, S.W.1, Annual General Meeting, 6 p.m.

Illuminating Engineering Society

To-day, Dec. 7th.—BATH AND BRISTOL CENTRE: S.W. Electricity Board Lecture Theatre, Colston Avenue, Bristol, "Lighting for the Prevention of Industrial Accidents," E. W. Murray, 6.15 p.m.——BIRMINGHAM CENTRE: Imperial Hotel, Temple Street, Birmingham, "The Architects' Approach to Artificial Lighting," R. G. Cox, 6 p.m.——HUDDERSFIELD GROUP: Electricity Showroom, Market Street, Huddersfield, "Lighting in the New House of Commons," C. Dykes Brown, 7.15 p.m.

Mon., Dec. 10th.—LEEDS CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Architecture and Lighting," 7 p.m.

Tues., Dec. 11th.—Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Dark Adaption," W. J. Wellwood Ferguson, 6 p.m.

Wed., Dec. 12th.—EDINBURGH CENTRE: Lighting and Cleansing Department, 357, High Street, Edinburgh, "Light and Crime," Wm. Merrilees, 7 p.m.

Thurs., Dec. 13th.—GLASGOW CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Church Lighting," L. C. Rettig, 6.30 p.m.——LEICESTER CENTRE: E. Midlands Electricity Board, Charles Street, Leicester, "What I Have Learned About Lighting from the Festival," T. O. Freeth, 6.30 p.m.——MANCHESTER CENTRE: Town Hall Extension, Manchester, "Brightness Engineering," W. Robinson, 6 p.m.

Incorporated Plant Engineers

Mon., Dec. 10th.—DUNDEE BRANCH: Mathers Hotel, Dundee, Address by H. E. Partridge, 7.30 p.m.

Tues., Dec. 11th.—E. LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, "Corrosion in Boiler Steamlines and Condensate Return Pipelines," G. S. Irving, 7.15 p.m.——EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, "Fifty Years' Apprenticeship," D. Frew, 7 p.m.

Wed., Dec. 12th.—E. MIDLANDS BRANCH: Welbeck Hotel, Nottingham, "Rocket Development and the Testing of Rocket Motors," J. Humphries, 7 p.m.

Thurs., Dec. 13th.—KENT BRANCH: Queen's Head, Maidstone, "Water Conditioning," 7 p.m.——NEWCASTLE UPON TYNE BRANCH: Roadway House, Oxford Street, Newcastle upon Tyne, Discussion Night, 7.30 p.m.

Institute of British Foundrymen

Tues., Dec. 11th.—SLOUGH SECTION: High Duty Alloys, Ltd., Slough, Bucks, "The Semi-Continuous Casting of Billets," J. Munday, 7.30 p.m.——COVENTRY AND DISTRICT STUDENTS' SECTION, Technical College, Coventry, "Some Developments in Cast Iron," H. Morrogh, 7.15 p.m.

Wed., Dec. 12th.—LONDON BRANCH: Waldorf Hotel, Aldwych, W.C.2, "Development of Aluminium Alloy Casting," A. P. Fenn, 7 p.m.——LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, "The Manufacture of Castings for the Smithy and Forge Industry," W. S. Spenceley, 7 p.m.

Thurs., Dec. 13th.—LINCOLNSHIRE BRANCH: Technical College, Lincoln, "Corrosion and Erosion of Cast Iron," R. I. Higgins, 7.15 p.m.

Fri., Dec. 14th.—MIDDLESBROUGH BRANCH: Head Wrightson and Co., Ltd., Teesdale Ironworks, Thornaby-on-Tees. "Patternmaking—Some Present-Day Practices," B. Levy, 7.30 p.m.

Institute of Industrial Supervisors

Tues., Dec. 11th.—KIDDERMINSTER SECTION: Brintons, Ltd., Kidderminster, "Industrial Sales Management," I. Mills, 7.30 p.m.

Wed., Dec. 12th.—W. BROMWICH SECTION: Grammar School, W. Bromwich, "The Art of Brewing," John Knox, 7.45 p.m.——N.W. SECTION: Unity Hall, Greek Street, Stockport, Members' Discussion Night, 8 p.m.

Thurs., Dec. 13th.—S.E. LONDON SECTION: The Polytechnic, Woolwich, "Problems in Large Scale Organisation," J. W. Graely, 6.30 p.m.——COVENTRY SECTION: Craven Arms Hotel, High Street, Coventry, "The Manufacture of Glass," R. E. Bastick, 7.30 p.m.

Institute of Marine Engineers

Tues., Dec. 11th.—85, Minories, London, E.C.3, "Ductile Cast Iron," M. M. Hallett, 5.30 p.m.

Thurs., Dec. 13th.—Poplar Technical College, Poplar High Street, E.14, "Welding in Ship Repair Work," J. W. Coulthard, 7.15 p.m.

Institute of Metals

To-day, Dec. 7th.—SHEFFIELD LOCAL CENTRE: The University, St. George's Square, Sheffield, "Precious Metals in Industry," H. G. Dale, 6.30 p.m.

Mon., Dec. 10th.—SCOTTISH LOCAL SECTION: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, Symposium on "Materials Testing," 6.30 p.m.

Wed., Dec. 12th.—LONDON LOCAL SECTION: Waldorf Hotel, Aldwych, W.C.2, "The Development of Aluminium Alloy Casting," A. P. Fenn, 7 p.m.

Institute of Petroleum

Wed., Dec. 12th.—Manson House, 26, Portland Place, London, W.1, "Pre-Flame Reactions in a Diesel Engine," F. H. Garner, F. Morton, W. D. Reid, E. P. Wright and W. E. Malpas, 5.30 p.m.

Institute of Refrigeration

Thurs., Dec. 13th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, A Symposium on "The Control and Measurement of Humidity in Cold Stores," 5 p.m.

Institute of Road Transport Engineers

Wed., Dec. 12th.—E. MIDLANDS CENTRE: Mechanics Institute, Nottingham, "Gearbox Transmission and Rear Axles," R. T. Radcliffe, 7.30 p.m.

Thurs., Dec. 13th.—Royal Society of Arts, John Adam Street, London, W.C.2, "Experimental, Production and General Testing of R.T. Vehicles," L. J. Cotton, 7.30 p.m.

Fri., Dec. 14th.—S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, "Vacuum and Air Brakes," S. H. Edge, 7 p.m.

Institution of Civil Engineers

Tues., Dec. 11th.—Great George Street, Westminster, London, S.W.1, "The Construction of Kafr el Zayat Railway Bridge," K. E. Hyatt and G. W. Morley, 5.30 p.m.

Thurs., Dec. 13th.—MIDLANDS ASSOCIATION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Electro Chemical Hardening of Clays to Increase Bearing Capacity of Piles," J. Kolbuszewski, 6 p.m.——N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "Some Impressions of Civil Engineering in Australia," J. A. L. Matheson, 6.30 p.m.

Fri., Dec. 14th.—YORKSHIRE ASSOCIATION: Royal Victoria Station Hotel, Sheffield, "The Rapid Calculation of the Plastic Collapse Load of a Framed Structure," B. G. Neal, 7 p.m.

Institution of Electrical Engineers

Sat., Dec. 8th.—N. MIDLAND STUDENTS' SECTION: The University, Leeds, "Electric Safety," T. J. Wynn, 2.30 p.m.

Mon., Dec. 10th.—LONDON STUDENTS' SECTION: Savoy Place, W.C.2, "The van de Graaff Generator as a Million Volt D.C. Source," D. H. Homis and R. J. Ryan, 7 p.m.——S. MIDLAND SUPPLY AND UTILISATION GROUP: Grand Hotel, Colmore Row, Birmingham, "Motive Power in the Factory," Mr. Dreghorn, 6.15 p.m.

Tues., Dec. 11th.—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, "A Graphical Analysis for Non-Linear Systems," Miss Pei-Su Hsia, "A System Utilising Coarse and Fine Position Measuring Elements Simultaneously in R.P.C. Servo-Mechanisms," J. C. West, 5.30 p.m.——N. MIDLAND CENTRE: British Electricity Authority, 1, Whitehall Road, Leeds, 1, "Load Shedding," H. C. Ogden and H. Lloyd, 6.30 p.m.——SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Nuclear Particle and Radiation Detectors," D. Taylor and J. Sharpe, 7 p.m.

Wed., Dec. 12th.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "Activity Methods in Technical Education," opened by R. D. Watts, 6 p.m.

Thurs., Dec. 13th.—UTILISATION SECTION: Savoy Place, London, W.C.2, "The Characteristics and Control of Rectifier-Motor Variable-Speed Drives," P. Bingley, 5.30 p.m.

Institution of Mechanical Engineers

To-day, Dec. 7th.—Storey's Gate, St. James's Park, London, S.W.1, "The Measurement and Interpretation of Machinery Noise with Special Reference to Oil Engines," C. H. Bradbury, 5.30 p.m.——N.E. BRANCH: GRADUATES' SECTION: Northern Gas Board Showrooms, Grainger Street, Newcastle upon Tyne, "Brittle Lacquers," H. A. Slyper, 7 p.m.——SCOTTISH BRANCH: Technical College, Dundee, "Some Milestones in a Hundred Years of Marine Engineering," Edward L. Denny, 7.30 p.m.

Mon., Dec. 10th.—BIRMINGHAM A.D. CENTRE: James Watt Memorial Institute, York House, Great Charles Street, Birmingham, "Tyres and the M.I.R.A. Proving Ground," A. Fogg, 6.45 p.m.——LUTON A.D. CENTRE: Town Hall, Luton, "Life Assessment Methods for Trucks, Vans and 'Buses," J. H. Alden, 7.15 p.m.

Tues., Dec. 11th.—AUTOMOBILE DIVISION: Storey's Gate, St. James's Park, London, S.W.1, Discussion on "Trailers and Semi-Trailers," Arthur Marenbon, 5.30 p.m.——S. WALES BRANCH: Mackworth Hotel, Swansea, "The Principles of Continuous Gauge Control in Sheet and Strip-Rolling," W. C. F. Hessenberg and R. B. Sims, 6 p.m.——WESTERN BRANCH: Arts Centre, Swindon, "The Development of British Tanks Over the Last Twenty-Five Years," D. M. Ryeroft, 7 p.m.

Wed., Dec. 12th.—SOUTHERN BRANCH: University College, Southampton, "Thirty Years' Development of Opposed-piston Propelling Machinery," W. H. Purdie, 7 p.m.——S. WALES BRANCH: King's Head Hotel, Newport, "The Principles of Continuous Gauge Control in Sheet and Strip-Rolling," W. C. F. Hessenberg and R. B. Sims, 6 p.m.——WESTERN BRANCH, GRADUATES' SECTION: College of Technology, Unity Street, Bristol, "To-morrow's Workman," F. J. Hamer, 7 p.m.

Thurs., Dec. 13th.—SOUTHERN BRANCH, GRADUATES' SECTION: Royal Aircraft Establishment Technical College, Farnborough, "Our Institution," T. Irvine Hudson, 6.30 p.m.——YORKSHIRE BRANCH: The University, Leeds, "Theory and Practice in Bearing Design," D. G. Christopherson, 7 p.m.

Fri., Dec. 14th.—Storey's Gate, St. James's Park, London, S.W.1, Discussion on "Hydraulic Control Valves," B. Cooke, and "Hydraulic Power Transmission," A. E. Bingham, 5.30 p.m.

Institution of Post Office Electrical Engineers

To-day, Dec. 7th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The Application of Machinery to the Sorting of Parcels," P. E. C. Smith and H. J. Langton, 5 p.m.

Institution of Production Engineers

Mon., Dec. 10th.—SHEFFIELD BRANCH: Royal Victoria Station Hotel, Sheffield, "Oil Injection Method for Uniting and Separating Pressure Joints," C. S. Clarke, 6.30 p.m.

Wed., Dec. 12th.—BIRMINGHAM BRANCH: Grand Hotel, Birmingham, "Automatic Production Methods—with Special Reference to the Automotive Industry," T. U. Matthew, 7 p.m.——LONDON GRADUATE SECTION: 36, Portman Square, W.1, "Zinc Alloy Die-Casting," A. K. Parker, 7.15 p.m.

Institution of Sanitary Engineers

Tues., Dec. 11th.—Caxton Hall, Westminster, London, S.W.1, Discussion on "One-Pipe Plumbing—Some Recent Experimental Hydraulics at the Building Research Station," A. F. E. Wise, 5.30 p.m.

Institution of Structural Engineers

Wed., Dec. 12th.—YORKSHIRE BRANCH: Great Northern Hotel, Leeds, "The New House of Commons—Foundations and Structure," S. Vaughan, 6.30 p.m.

Thurs., Dec. 13th.—11, Upper Belgrave Street, London, S.W.1, "Construction of the Temple Barrage on the River Lot," L. P. Brice, 5.55 p.m.

Fri., Dec. 14th.—WALES AND MONMOUTHSHIRE BRANCH: County Buildings, Colwyn Bay, "Piling with Particular Regard to Sea Defence Works," J. Owen Lake, 6 p.m.

Iron and Steel Institute

Wed., Dec. 12th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Symposium on the Corrosion of Buried Metals, 10 a.m.

Junior Institution of Engineers

To-day, Dec. 7th.—39, Victoria Street, London, S.W.1, Film Evening, "Arc Welding," 6.30 p.m.

Fri., Dec. 14th.—Royal Society of Arts, John Adam Street, London, W.C.2, Presidential Address, F. R. Banks, "Enterprise in Engineering," 7.30 p.m.

Liverpool Engineering Society

Wed., Dec. 12th.—24, Dale Street, Liverpool, "The Liverpool Overhead Railway—A Pioneer in Rapid Transit," H. M. Rostron, 6 p.m.

Liverpool Metallurgical Society

Fri., Dec. 14th.—Electricity Service Centre, Whitechapel, Liverpool, "Metallic Coatings," D. L. Phillips, 7 p.m.

North-East Coast Institution of Engineers and Shipbuilders

To-day Dec. 7th.—Mining Institute, Newcastle upon Tyne, "External Ship Corrosion Due to Bacterial Action," W. S. Patterson, 6.15 p.m.

Royal Aeronautical Society

Tues., Dec. 11th.—GRADUATE AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, "Naval Aircraft," D. L. Hollis Williams, 7.30 p.m.

Sheffield Metallurgical Association

Tues., Dec. 11th.—Grand Hotel, Sheffield, "Resistance of Gas Turbine Alloys to Scaling and Vanadium Attack," H. C. Child, "The Evaluation of Residual Stresses in Metals by X-Rays," L. G. Finch, 7 p.m.

Societe des Ingenieurs Civils de France

Thurs., Dec. 13th.—British Section: Institution of Structural Engineers, 11, Upper Belgrave Street, S.W.1. "The Construction of the Temple Barrage on the River Lot," L. P. Brice. 6 p.m.

Catalogues

MINIATURE BEARINGS, Ltd., 192, Sloane Street, London, S.W.1.—Catalogue No. 4 of Miniature bearings.

JEFFREY-DIAMOND, Ltd., Stennard Works, Wakefield.—Publication giving details of rigid hammer crushers.

BLAW KNOX, Ltd., 94, Brompton Road, London, S.W.3.—Publication No. BK-147. Lightweight folding weigher.

PHILIPS ELECTRICAL, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.—Illustrated brochure containing technical information on the type "48" electrode for the welding of mild steels.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., Press Information Office, 21, Bloomsbury Street, London, W.C.1.—Publication dealing with (*a*) Mining type straight joint box; (*b*) Television downlead cables; (*c*) Terminal boxes for telephone and auxiliary circuits; (*d*) Aluminium-sheathed cables.